

(19)日本国特許庁 (J P)

(12) 公 開 特 許 公 報 (A)

(11)特許出願公開番号  
特開2001-53338  
(P2001-53338A)

(43)公開日 平成13年2月23日(2001.2.23)

(51)Int.Cl. <sup>7</sup>	識別記号	F I .	テ-マコード*(参考)
H 0 1 L 33/00		H 0 1 L 33/00	C 5 F 0 4 1
21/205		21/205	5 F 0 4 5
H 0 1 S 5/32		H 0 1 S 5/32	5 F 0 7 3

審査請求 未請求 請求項の数11 O L (全 9 頁)

(21)出願番号 特願平11-227075

(22)出願日 平成11年8月11日(1999.8.11)

(71)出願人 000002004

昭和電工株式会社

東京都港区芝大門1丁目13番9号

(72)発明者 宇田川 隆

埼玉県秩父市下影森1505番地 昭和電工株式会社総合研究所秩父研究室内

(72)発明者 三木 久幸

埼玉県秩父市下影森1505番地 昭和電工株式会社総合研究所秩父研究室内

(74)代理人 100094237

弁理士 矢口 平

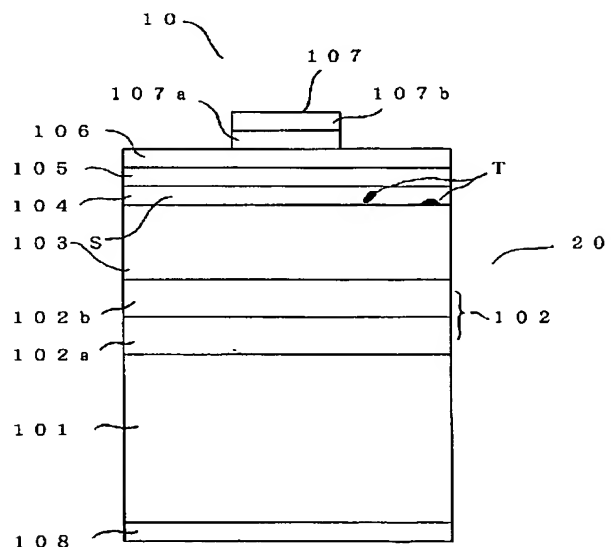
最終頁に続く

(54)【発明の名称】 I I I 族窒化物半導体発光素子

(57)【要約】

【課題】 I I I 族窒化物半導体からなる発光層を含む p n 接合型ヘテロ接合構造の発光部を具備した I I I 族窒化物半導体発光素子にあって、形成するのが煩雑な p 形 I I I 族窒化物半導体層に代替して、簡便に形成できる低抵抗の p 形導電層を p 形障壁層として、 p n 接合型ヘテロ接合構造の発光部を構成する。

【解決手段】 p 形伝導を呈する導電性酸化物材料からなる p 形障壁層を利用して p n 接合型ヘテロ構造の発光部を構成する。 p 形の透明酸化物材料から構成される p 形障壁層は、 p 形障壁層及び p 形ウィンドウ層として兼用できるので、高輝度の I I I 族窒化物半導体発光素子が提供できる。



## 【特許請求の範囲】

【請求項1】発光部として、n形のⅢⅤ族窒化物半導体からなる障壁層と、インジウム含有ⅢⅤ族窒化物半導体からなる発光層と、酸化物からなるp形層とを含むことを特徴とするⅢⅤ族窒化物半導体発光素子。

【請求項2】発光層が、インジウム濃度を相違する複数相のⅢⅤ族窒化物半導体（多層構造発光層）から構成されていることを特徴とする請求項1に記載のⅢⅤ族窒化物半導体発光素子。

【請求項3】酸化物からなるp形層の禁止帯幅が、発光層から出射される発光波長に対応する禁止帯幅より大きいことを特徴とする請求項1または2に記載のⅢⅤ族窒化物半導体発光素子。

【請求項4】酸化物からなるp形層が、400nm～600nmの波長の発光に対して、40%以上の透過率を有することを特徴とする請求項1～3の何れか1項に記載のⅢⅤ族窒化物半導体発光素子。

【請求項5】酸化物からなるp形層の禁止帯幅が、多層構造発光層を構成する主体相の禁止帯幅以上であることを特徴とする請求項2～4の何れか1項に記載のⅢⅤ族窒化物半導体発光素子。

【請求項6】酸化物からなるp形層の禁止帯幅と、多層構造発光層を構成する主体相の禁止帯幅との差異が1.0eV以下であることを特徴とする請求項5に記載のⅢⅤ族窒化物半導体発光素子。

【請求項7】酸化物からなるp形層が、銅を含む酸化物から構成されていることを特徴とする請求項1～6の何れか1項に記載のⅢⅤ族窒化物半導体発光素子。

【請求項8】酸化物からなるp形層が、CuAlO<sub>2</sub>であることを特徴とする請求項7に記載のⅢⅤ族窒化物半導体発光素子。

【請求項9】酸化物からなるp形層の層厚が、5nm～500nmであることを特徴とする請求項8に記載のⅢⅤ族窒化物半導体発光素子。

【請求項10】CuAlO<sub>2</sub>が、多結晶体であることを特徴とする請求項8または9に記載のⅢⅤ族窒化物半導体発光素子。

【請求項11】酸化物からなるp形層と発光層との間に、 $Al_xGa_yIn_zN$  ( $0 < X \leq 1$ ,  $0 \leq Y < 1$ ,  $X + Y + Z = 1$ ) で表記されるⅢⅤ族窒化物半導体層が備えられていることを特徴とする請求項1～10の何れか1項に記載のⅢⅤ族窒化物半導体発光素子。

## 【発明の詳細な説明】

## 【0001】

【発明の属する技術分野】ⅢⅤ族窒化物半導体以外のp形伝導層から構成される、pn接合型ヘテロ構造の発光部を備えたⅢⅤ族窒化物半導体発光素子に関する。

## 【0002】

【従来の技術】従来の青色帯或いは緑色帯の発光を呈する発光ダイオード(LED)或いはレーザダイオード

(LD)は、有機金属熱分解気相成長(MOCVD)法によりサファイア( $\alpha-Al_2O_3$ 単結晶)基板上にエピタキシャル成長されたⅢⅤ族窒化物半導体結晶層を備えた積層構造体を母体としてもつばら構成されている

(例えば、Jpn. J. Appl. Phys., Vol. 34, Part 2, No. 10B (1995)、L1332～L1335頁参照)。サファイアに代替して、炭化珪素(SiC)を基板とした窒化ガリウム(GaN)系エピタキシャル構造体からLDを構成する従来技術もある(「応用物理」、第68巻第7号(1999)、797～800頁参照)。また、珪素(Si)単結晶を基板とし、分子線エピタキシャル(MBE)法で成膜した窒化アルミニウム(AlN)を含む積層構造体から青色LEDを構成する例も知られている(Electron. Lett., Vol. 33, No. 23 (1997)、1986～1987頁参照)。此处で云うⅢⅤ族窒化物半導体とは、窒素(N)をV族構成元素として含む、一般式 $Al_xGa_yIn_zN$  ( $0 \leq X \leq 1$ ,  $0 \leq Y < 1$ ,  $X + Y + Z = 1$ )や、 $Al_xGa_yIn_zN_{1-Q}M_Q$  ( $0 \leq X < 1$ ,  $0 \leq Y < 1$ ,  $X + Y + Z = 1$ 、記号Mは窒素以外の第V族元素であり、 $0 \leq Q < 1$ )で表記されるⅢⅤ族化合物半導体である。

【0003】LED或いはLD等のⅢⅤ族窒化物半導体発光素子に於いて、窒化ガリウム・インジウム( $Ga_xIn_{1-x}N$ :  $0 \leq X \leq 1$ )は、短波長可視光を放射するのに適する禁止帯幅を有するが故に、ⅢⅤ族窒化物半導体発光素子の発光層として活用されている(特公昭55-3834号参照)。また、これらの発光素子の発光部は、高強度の短波長可視光を獲得する目的で、pn接合型のダブルヘテロ(DH)構造から構成されているのが一般的である(例えば、上記のJpn. J. Appl. Phys., Vol. 34 (1995)参照)。更に、インジウム組成( $=1-X$ )を相違する複数の相(phase)からなる多相(multi-phase)構造からなる $Ga_xIn_{1-x}N$  ( $0 \leq X \leq 1$ )から発光層を構成して、高輝度のⅢⅤ族窒化物半導体発光素子を得る技術も開示されている(アメリカ合衆国特許US-5,886,367号参照)。

【0004】従来のpn接合型のDH構造にあつて、発光層を挟持するp形或いはn形障壁層は、一般にp形或いはn形の窒化アルミニウム・ガリウム( $Al_xGa_{1-x}N$ :  $0 \leq X \leq 1$ )等のⅢⅤ族窒化物半導体から構成される。GaN系材料は不純物を故意に添加しない、所謂、アンドープ(undoped)状態でn形の伝導を呈するため(特開昭53-20882号公報明細書参照)、n形の $Al_xGa_{1-x}N$ 層は成膜し易いのは周知である。一方、p形の $Al_xGa_{1-x}N$ 層はもつばら、マグネシウム(Mg)をp形不純物としてドーピングする手段をもって成膜されている。しかしながら、その成膜時に成長層内に侵入する水素により、Mgが電気的に不活

性化される（特許第2872096号公報参照）。このため、 $a-s-grown$ 状態では低抵抗のp形 $Al_xGa_{1-x}N$ 層が安定して得られないのも公知となっている（特開昭61-7671号公報明細書参照）。

【0005】pn接合型のDH構造を構成するのに必要とされる低抵抗のp形 $Al_xGa_{1-x}N$ 層を得るために、従来では、一旦成膜したp形不純物がドーピングされた $a-s-grown$ 成長層に対し、成膜後に400℃を以上の温度で熱処理する手段が採用されている（特許第2540791号参照）。或いは、 $a-s-grown$ 状態のp形不純物が添加された $Al_xGa_{1-x}N$ 成長層を真空環境下に於いて、電子線を照射してp形不純物を電気的に活性化させる手段が採られている（特許第2500319号参照）。

【0006】従来では、p形III族化合物半導体成長層の表面側から発光を外部に取り出す構成が大勢である。即ち、発光層の上部に配置された例えば、p形 $Al_xGa_{1-x}As$ （ $0 \leq X \leq 1$ ）障壁層側から発光を外部に取り出す構成となっている。このため、従来型のGaN系LEDにあっては、上部障壁層の上方に設ける電極は、外部への発光の取り出し効率を向上させるために、透明或いは透光性の材料から主に構成されている。例えば、p形不純物を添加したGaN系半導体層を介して、酸化インジウム・錫（略称：ITO）からなる透明電極と、その透明電極上に金（Au）とニッケル（Ni）の重層構造からなる電極を設ける構成が開示されている（特許第2661009号参照）。AuとNiとの間に酸化ニッケル（NiO）を挿入した構成からなる電極は透光性であることが知られている（特許第2916424号参照）。また、p形GaNからなるコンタクト（contact）層を介在させて、アルミニウム（Al）が添加された酸化亜鉛（ZnO）層をAu電極のオーミック接触層として配置する技術が開示されている（アメリカ合衆国特許US5,889,295号参照）。

【0007】

【発明が解決しようとする課題】上記の如く、エピタキシャル成長法により成膜されたIII族窒化物半導体成長層を利用して、pn接合型の発光部を構成する手段は煩雑である。特に、低抵抗のp形III族窒化物半導体層を得るためのエピタキシャル成長後に、p形不純物を電気的に活性化させるための特別の処理を要することが、工程の煩雑性を増し、III族窒化物半導体発光素子の生産効率を著しく低下させる一因ともなっている。この従来技術に於ける問題点は、例えば、p形のIII族窒化物半導体結晶層とは別の、簡便なる手段をもって形成できる低抵抗の材料から正孔（hole）供給層を構成する手段により解決が図られるものと想到される。

【0008】また、透明酸化物からなる透明電極をp形不純物がドーピングされたIII族窒化物半導体層上に直接設ける従来の構成では、電極を構成する透明酸化物

材料とIII族窒化物半導体層とで良好なオーミック（Ohmic）接触性が安定して発現されない不都合がある。これは、発光素子を構成するIII族窒化物半導体結晶層と透明酸化物電極との禁止帯幅の差異が、極めて大となっていることにも起因している。このため、LEDにあっては順方向電圧（所謂、 $V_f$ ）、LDにあっては閾値電圧（所謂、 $V_{th}$ ）を効果的に低減できないという問題を生じている。

【0009】透明導電性酸化物層とLED構成層とのオーミック接触性を高める施策の例は、リン化アルミニウム・ガリウム・インジウム（ $(Al_xGa_{1-x})_{1-y}In_yP$ ： $0 \leq X \leq 1$ 、 $0 < Y \leq 1$ ）LEDに関する従来技術に見て取れる。例えば特開平11-17220号に記載される発明では、砒化ガリウム（GaAs）や砒化リン化ガリウム（GaAsP）等を、オーミック接触性の向上を期すコンタクト層として挿入した上で、透明酸化物層を重層させている。また、特開平11-4020号公報に記載される発明では、ITOやZnOなどの透明酸化物層直下のp形化合物半導体層全面に、亜鉛（Zn）膜或いはAu・Zn合金膜を一樣に配置する構成からなるAlGaInP系LEDが開示されている。

【0010】しかし、赤橙色或いは黄色帯域の発光を放射するAlGaInP系LEDに係わる上記の従来技術を、より短波長の青色或いは緑色帯域のIII族窒化物半導体発光素子に単純に流用すると、外部への発光の透過効率を低下させる不都合を生ずる。上記の金属膜では尚更のこと、コンタクト層を構成する例えば、GaAsでも、禁止帯幅が青色光或いは緑色光に相応する禁止帯幅に比べ小さいため、発光が吸収されてしまう。即ち、透明酸化物層とのオーミック接触性を良好にするために金属膜を配置する手段や、透過すべき発光の波長から換算される禁止帯幅より小とする半導体材料からなる電極形成（コンタクト）層を配置する従来の手段は、高輝度のIII族窒化物半導体発光素子には十分に応用できない。

【0011】 $Ga_xIn_{1-x}N$ （ $0 \leq X \leq 1$ ）発光層から出射される短波長の発光を透過するのに十分な性能を有し、併せて、III族窒化物半導体材料の場合とは異なる、低抵抗のp形の透明材料で、pn接合型ヘテロ接合構造の発光部を構成すれば、高輝度のIII族窒化物半導体発光素子が提供できる。また、III族窒化物半導体発光素子を構成するIII族窒化物半導体構成層との良好なオーミック接触性を顕現する材料であれば、高輝度のIII族窒化物半導体発光素子を獲得するのに更に好都合となる。しかしながら、現状に於いて、この様な要求を満足させる構成は開示されるに至っていない。特に、高強度の発光をもたらすことが知られている多相構造の $Ga_xIn_{1-x}N$ （ $0 \leq X \leq 1$ ）からなる発光層について（英国特許GB2316226B参照）、発光の透過性に優れるp形の透明導電性材料と良好なオーミック

接触特性を発現するための要件は未知となっている。

【0012】本発明は、上記の従来技術が抱える技術上の問題点を克服し、高輝度のⅢⅢ族窒化物半導体発光素子を簡便に且つ安定して提供することを目的となされたもので、特に、容易に形成可能なp形の伝導層を用いてpn接合型のヘテロ構造の発光部を構成するために必須の要件を、発光層の禁止帯幅を基準として提示するものである。

【0013】

【課題を解決するための手段】発明者は、上記の課題を解決すべく鋭意努力検討した結果、本発明に到達した。即ち、本発明は、[1] 発光部として、n形のⅢⅢ族窒化物半導体からなる障壁層と、インジウム含有ⅢⅢ族窒化物半導体からなる発光層と、酸化物からなるp形層とを含むことを特徴とするⅢⅢ族窒化物半導体発光素子、[2] 発光層が、インジウム濃度を相違する複数相のⅢⅢ族窒化物半導体（多層構造発光層）から構成されていることを特徴とする[1]に記載のⅢⅢ族窒化物半導体発光素子、[3] 酸化物からなるp形層の禁止帯幅が、発光層から出射される発光波長に対応する禁止帯幅より大きいことを特徴とする[1]または[2]に記載のⅢⅢ族窒化物半導体発光素子、[4] 酸化物からなるp形層が、400nm～600nmの波長の発光に対して、40%以上の透過率を有することを特徴とする[1]～[3]の何れか1項に記載のⅢⅢ族窒化物半導体発光素子、[5] 酸化物からなるp形層の禁止帯幅が、多層構造発光層を構成する主体相の禁止帯幅以上であることを特徴とする[2]～[4]の何れか1項に記載のⅢⅢ族窒化物半導体発光素子、[6] 酸化物からなるp形層の禁止帯幅と、多層構造発光層を構成する主体相の禁止帯幅との差異が1.0eV以下であることを特徴とする[5]に記載のⅢⅢ族窒化物半導体発光素子、[7] 酸化物からなるp形層が、銅を含む酸化物から構成されていることを特徴とする[1]～[6]の何れか1項に記載のⅢⅢ族窒化物半導体発光素子、[8] 酸化物からなるp形層が、CuAlO<sub>2</sub>であることを特徴とする[7]に記載のⅢⅢ族窒化物半導体発光素子、[9] 酸化物からなるp形層の層厚が、5nm～500nmであることを特徴とする[8]に記載のⅢⅢ族窒化物半導体発光素子、[10] CuAlO<sub>2</sub>が、多結晶体であることを特徴とする[8]または[9]に記載のⅢⅢ族窒化物半導体発光素子、[11] 酸化物からなるp形層と発光層との間に、Al<sub>x</sub>Ga<sub>y</sub>In<sub>z</sub>N（0<X≤1、0≤Y<1、X+Y+Z=1）で表記されるⅢⅢ族窒化物半導体層が備えられていることを特徴とする[1]～[10]の何れか1項に記載のⅢⅢ族窒化物半導体発光素子、に関する。

【0014】

【発明の実施の形態】本発明の第1の実施形態に於ける特徴は、pn接合型ヘテロ接合構造の発光部を構成する

p形層をp形ⅢⅢ族窒化物半導体材料からではなく、p形の伝導性を呈する酸化物材料から構成することにある。酸化物材料としては、例えば、酸化銅（Cu<sub>2</sub>O）や酸化ランタン・ストロンチウム・銅（La<sub>1-x</sub> Sr<sub>x</sub> CuO<sub>2</sub>；X=1または2）（Mat. Res. Soc. Symp. Proc., Vol. 156（1989）、183～188頁参照）などのペロブスカイト結晶から構成できる。また、酸化ランタン・カルシウム・ロジウム（La<sub>1-x</sub> Ca<sub>x</sub> RhO<sub>3</sub>）、酸化ランタン・ストロンチウム・ロジウム（La<sub>1-x</sub> Sr<sub>x</sub> RhO<sub>3</sub>）や酸化ランタン・バリウム・ロジウム（La<sub>1-x</sub> Ba<sub>x</sub> RhO<sub>3</sub>）等の超伝導酸化物材料（「物性科学選書 電気伝導性酸化物（改訂版）」（（株）裳華房、1997年8月10日発行、改訂第6版）、29頁参照）からも構成できる。

【0015】n形或いはp形のGa<sub>x</sub>In<sub>1-x</sub>N（0≤X≤1）などからなる発光層から出射される発光の波長に対応する禁止帯幅を越え、且つ発光層の禁止帯幅を越える禁止帯幅を有するp形伝導性の酸化物材料からは、p形の障壁層を兼用する透明p形電極層が構成でき好ましい。即ち、本発明に依れば、p形障壁層をⅢⅢ族窒化物半導体材料から構成し、成膜後に後処理工程を必要とする従来技術の煩雑さが回避でき、尚且、障壁（clad）機能を兼用する透明電極層を具備したpn接合ヘテロ構造の発光部が構成できる。pn接合ヘテロ発光部とは、n形若しくはp形の単一の発光層をp形及びn形双方の障壁層とで挟持してなるヘテロ構造であり、或いは単一或いは多重量子井戸構造を挟持してなるpn接合型ヘテロ発光部である。例えば、n形Ga<sub>x</sub>In<sub>1-x</sub>N（0≤X≤1）井戸層・n形Al<sub>x</sub>Ga<sub>1-x</sub>N（0≤X≤1）障壁層からなる量子井戸構造発光層/p形酸化物障壁層からなるpn接合型発光部の構成がある。量子井戸構造の発光層にあって、n形並びにp形障壁層に接合させるのは、井戸層或いは障壁層の何れであって第1の実施形態に含まれる。

【0016】本発明の第2の実施形態では、発光層をインジウム濃度を相違する多相構造のⅢⅢ族窒化物半導体で構成すると高強度の発光がもたらされ、特にⅢⅢ族窒化物半導体をGa<sub>x</sub>In<sub>1-x</sub>N（0≤X≤1）とするより好適な発光層を構成できる。

【0017】多相構造とは具体的には、体積的に発光層の大部分を占有する主体相（matrix-phase）と、主体相より占有する体積は小とするものの、インジウム組成（濃度）を主体相より大とする従属相（sub-phase）とから構成される内部結晶組織構造である（特開平10-56202号公報明細書参照）。従属相は通常は、主体相内に散在する微結晶体として存在する。形状を例えば、略球形で且つその直径を均一とするには、Ga<sub>x</sub>In<sub>1-x</sub>N（0≤X≤1）発光層の成膜終了後に当該発光層が被る昇温或いは降温、冷却サイクルに於ける昇温速度若しくは冷却速度の調節をもって達

成できる（上記の英国特許GB2316226B参照）。この様な内部結晶組織構成を有する発光層にp形伝導性の酸化物層を組み合わせた構成とすれば、高強度の発光をもたらすpn接合型ヘテロ構造の発光部が簡便に構成できる利点がある。

【0018】本発明の第3の実施形態では、発光層の内部結晶組織の如何に拘わらず、p形酸化物層を、発光層からの発光波長に相応する禁止帯幅を越える禁止帯幅の材料から構成すると、外部への発光の透過層（窓（ウィンドウ）層）をも兼ねるp形酸化物層が構成でき得て利便である。p形酸化物層は好ましくは、発光層のバンドギャップ（band-gap）より約0.1〜約0.3エレクトロンボルト（単位：eV）高くすると、発光を透過する上でも、また、障壁作用を発揮させる上でも好都合となる。特に、第4の実施形態に記す如く、インジウム含有III族窒化物半導体発光層から放射される波長にして400nm〜600nmの範囲にある発光について、40%以上の透過率を発揮するp形酸化物は、高輝度のLEDを得るのに特に好適に利用できる。透過率は高ければ高い程、高輝度のLEDを得るに好都合である。透過率が40%未満であると急激に外部への発光の取り出し効率が悪化する。

【0019】 $Ga_xIn_{1-x}N$  ( $0 \leq x \leq 1$ ) にあって、インジウム組成比が大となれば禁止帯幅は小となる（前出の特公昭55-3834号参照）。従って、例えば、多相構造の $Ga_xIn_{1-x}N$  ( $0 \leq x \leq 1$ ) からなる発光層にあって、従属相を構成する $Ga_{x1}In_{1-x1}N$  ( $0 < x1 \leq 1$ ) の禁止帯幅は、主体相をなす $Ga_{x2}In_{1-x2}N$  ( $0 \leq x2 < x1 < 1$ ) のそれより小である。従属相を基準として、それよりも禁止帯幅を大とする酸化物材料を選択したとて、必ずしも主体相の禁止帯幅を上回るとは限らない。従属相よりも禁止帯幅を大として、主体相を下回る禁止帯幅のp形酸化物層を接合させると、多相構造発光層とp形酸化物層との接合界面で伝導帯或いは価電子帯のポテンシャルの“落ち込み”が発生するため、キャリア（担体）に及ぼすクラディング（cladding）作用が弱体化し、発光層への「キャリアの閉じ込め」が充分ではなくなる。従って、高強度の発光を得るのに不都合となる。故に、第5の実施形態では、禁止帯幅を相違する成分からなる多相構造の発光層を用いた場合のp形酸化物層は、主体相の禁止帯幅を基準にして、それよりも禁止帯幅を大とする酸化物材料から構成する。

【0020】しかし、p形酸化物層と発光層とのポテンシャル障壁が不必要に高いと、「発光の閉じ込め」効果は発揮されるものの、キャリア（担体）の流通が阻害され、しいてはVf或いはVthを徒に上昇させる不都合が生ずる。従って、第6の実施形態では、p形酸化物層の禁止帯幅と、発光層の主体相の禁止帯幅との差を、1.0eVを以下とする材料から構成するものとする。

【0021】第7の実施形態に記す如く、銅（Cu）を構成元素として含む酸化物結晶は、一般にその他の酸化物結晶に比較すれば、低い（小さい）抵抗値を与える酸化物が得られる。従って、銅を構成元素とするp形酸化物結晶層は、本発明の実施形態のpn接合発光部を構成するのに都合良く利用できる。銅を構成元素とする酸化物結晶には上記の $Cu_2O$ や酸化アルミニウム・銅（ $CuAlO_2$ ）、酸化ストロンチウム・銅（ $CuSrO_2$ ）、酸化ガリウム・銅（ $CuGaO_2$ ）などのデラフォサイト（delafossite）結晶型（ $CuMO_2$ ：Mは3価の金属イオン）がある。

【0022】特に、 $CuAlO_2$ は、一般的なスパッタリング（sputtering）法或いはレーザーアブレーション（laser ablation）法により、抵抗率にして $1\Omega \cdot cm$ の低抵抗p形結晶層が簡便に成膜できる（“Nature”、Vol. 389、No. 6654（1997）、939〜942頁参照）。従って、 $CuAlO_2$ からは、成膜後に別途、低抵抗化のための煩雑な後工程を要せずに、p形電極層を構成するに足るp形酸化物層が得られる利点がある。また、 $CuAlO_2$ は、室温で禁止帯幅を約3.5eVとする透明導電性結晶である（上記の“Nature”、Vol. 389参照）。従って、 $CuAlO_2$ からは、 $Ga_xIn_{1-x}N$  ( $0 \leq x \leq 1$ ) 発光層から放射される近紫外帯域から緑色帯域の発光を透過するのに充分な発光透過層（ウィンドウ層）が構成できる。また、禁止帯幅を約3.4eVとするGaNとの禁止帯幅の差異は約0.1eVとなる。従って、 $CuAlO_2$ からは、例えば、GaNを主体相とする多相構造の $Ga_xIn_{1-x}N$  ( $0 \leq x \leq 1$ ) 発光層に対して、適度の障壁の高さをもって接合できる透明で且つp形の導電性を有する酸化物層が構成される。これ故に第8の実施形態では、p形酸化物層を $CuAlO_2$ から構成するのが好適とする。

【0023】第9の実施形態では、 $CuAlO_2$ の層厚を、好ましくは5nm以上に設定する。5nm未満では、発光層の表面の全面を均等に被覆するのに至らないからである。また、p形の $CuAlO_2$ をp形障壁層として、また正孔供給層として利用する本発明にあって、層厚が小であると発光層へ充分に正孔が供給できない。一方、500nmを越える厚さとするp形 $CuAlO_2$ 層の表面の凹凸が顕著となり、同層の表面での乱反射のため発光の外部への取り出し効率が顕著に低下する。従って、p形 $CuAlO_2$ 層の層厚は最大でも500nmに制限する。スパッタリング法或いはレーザーアブレーション法に依りp形 $CuAlO_2$ 層を成膜する場合に、同層の層厚は成膜時間を調整することをもって制御できる。

【0024】 $CuAlO_2$ を構成するCuは易拡散性の元素であり、III族窒化物半導体からなる発光層内に拡散、侵入する場合は有り得る。銅は、GaN等のII

I族窒化物半導体で発光中心 (color center) となる (J. Appl. Phys., Vol. 47, No. 12 (1976)、5387~5390頁参照)。従って、銅が混入したIII族窒化物半導体発光層からは単色性に優れる発光が得られ難くなる。本発明では、第9の実施形態に記す如く、p形CuAlO<sub>2</sub>結晶層を多結晶層から構成する。多結晶体とすれば、その中に多くの粒界を内在させることができる。多くの粒界を存在させておけば、その粒界により多量の銅が捉えられ、それだけ発光層への拡散を抑制できる。例えば、アルゴン (Ar) スパリング法により多結晶のp形CuAlO<sub>2</sub>結晶層を形成するには、一般には、成膜温度を室温から約500℃の範囲とするのが推奨される。形成したp形CuAlO<sub>2</sub>結晶層が多結晶で在るか否かは、X線回折分析法や電子線回折法等により確認できる。

【0025】p形酸化物層の構成元素、或いは含有不純物の、III族窒化物半導体発光層内への拡散、侵入をより効果的に抑止するには、第10の実施形態に示す如く、発光層とp形酸化物層との中間に、Alを含有するIII族窒化物半導体層を配置するのが有効となる。Alを含有するIII族窒化物半導体層は、Alが易酸化性であるために、上層の酸化物層から遊離して発光層に拡散、侵入して来る酸素を捕獲し、発光層が酸化されるのを抑制するのにも有効となる。また、Alを構成元素として含むIII族窒化物半導体は、インジウム含有III族窒化物半導体発光層を構成する主体相よりも禁止帯幅が一般的に大であり、従って、発光層からの発光を殆ど吸収することなく外部へ取り出せる効果がある。

【0026】発光層上に設けるAl含有III族窒化物半導体層はまた、その上にp形酸化物層を例えば、スパッタリング法で被着させる際の損傷から発光層を底護する保護層としても有用となる。発光層へ侵入するCu或いは酸素 (O) の濃度を低減し、且つ発光層の損傷を抑制するのに有効となるAl含有III族窒化物半導体層の層厚は大凡、1nmを越え約100nm以下の範囲である。III族窒化物半導体発光素子にあって、Al含有III族窒化物半導体層は、正孔供給層としてのp形酸化物層から供給される正孔 (hole) を効率的にトンネル (tunnel) 効果に依り発光層へ注入できる様に、層厚を2nm以上で50nm以下とする低キャリア濃度層であるのが好ましい。

【0027】また、Al含有III族窒化物半導体層のAl組成比は、発光層から放射される発光の波長に変化を与える効果を有する。例えば、窒化アルミニウム・ガリウム (Al<sub>x</sub>Ga<sub>1-x</sub>N: 0 ≤ x ≤ 1) からなる結晶層を上記の保護層或いは拡散防止層とした場合、同一の仕様の発光層から放射される発光の波長は、アルミニウム組成比 (= x) の増加と共に長波長となる。例えば、同一の層厚のGa<sub>0.88</sub>In<sub>0.12</sub>N発光層に、層厚を約20nmとするAl<sub>0.85</sub>Ga<sub>0.15</sub>N層を冠した場合の

発光波長は、約450nm~約460nmとなるのに対し、層厚を約20nmとするAl<sub>0.20</sub>Ga<sub>0.80</sub>N層を被着させた場合は約510nmから約530nmとなる。ちなみに、Al<sub>x</sub>Ga<sub>1-x</sub>N (0 ≤ x ≤ 1) 層を冠する場合、発光層の層厚が小さいほど、長波長の発光が帰結される傾向にある。これは、Al<sub>x</sub>Ga<sub>1-x</sub>N層とGa<sub>x</sub>In<sub>1-x</sub>N発光層との間において、発光層が被る歪みの大小により発光波長を変化させられることを示唆している。しかし、アルミニウム組成比があまりにも高いと、禁止帯幅は大となり発光を透光するのには良いが、素子動作電流の通流抵抗体となり兼ねない。それ故に、アルミニウム含有III族窒化物半導体のアルミニウム組成比は、高くとも約0.25~約0.30の範囲とするのが好ましい。

【0028】本発明に係わる発光素子は、上記の第1~10の実施形態に於けるp形酸化物層上にp形台座電極を被着させて構成する。本発明のp形酸化物層は、水平方向に素子動作電流を拡散できる導電層であるため、従来技術の如くp形III族窒化物半導体層の表面に取えて、Au-Ni或いはAu-NiO-Auの如くの透過性を悪化させる金属被膜を設けて電流拡散を果す必要はない。また、p形電極層をp形導電性の酸化物層から構成すると、オーミック接触性に優れる台座電極が形成され得る。p形台座電極は、公知のNi、NiO、Au-Zn合金、Au-ベリリウム (Be) 合金、In-Zn合金などから好適に構成できる。一方、n形のオーミック電極は、例えば、Ni、NiO、In、アンチモン (Sb)、酸化アンチモン、Au-Ge合金、Au-錫 (Sn) 合金、In-Sn合金から構成できる。珪素 (Si) 或いはSiCまたはリン化ガリウム (GaP) などの導電性結晶を基板とする場合では、基板の裏面側に設けることができ利便である。

【0029】

【実施例】 (実施例1) 本実施例では、p形障壁層、p形ウィンドウ層及びp形電極層 (コンタクト層) を兼ねる透明なp形導電性酸化物層を備えた積層構造体20から青色LED10を構成する場合を例にして、本発明を詳細に説明する。図1は本実施例に係わるLED10の断面模式図である。

【0030】積層構造体20は、Sbドープn形Si単結晶基板101、閃亜鉛鉱型の立方晶リン化硼素 (BP) を主体としてなる多結晶のn形の第1の緩衝層102a及び緩衝層102aより高温で成膜された立方晶BPを主体としてなるn形の第2の緩衝層102bからなるn形緩衝層102、Siドープn形GaNからなる下部障壁層103、主体相Sをn形GaNとし、平均的なインジウム組成比を0.1とする窒化ガリウム・インジウム混晶 (Ga<sub>0.9</sub>In<sub>0.1</sub>N) を従属相Tとする多相構造のn形発光層104、アンドープでn形のAl<sub>0.8</sub>Ga<sub>0.2</sub>Nからなる保護層105、及びCuAlO<sub>2</sub>からなる



る透明p形導電層106から構成した。

【0031】第1及び第2の緩衝層102a、102bは、トリエチル硼素( $(C_2H_5)_3B$ )を硼素(B)源とし、ホスフィン( $PH_3$ )をリン(P)源とするMOCVD法で成膜した。多結晶の第1の緩衝層102aは420℃で成膜し、単結晶の第2の緩衝層102bは、第1の緩衝層102aの成膜を終了した後、ホスフィンを含む雰囲気中で基板101の温度を1050℃に昇温して成膜した。エピタキシャル構成層102~105の各層は、トリメチルガリウム( $(CH_3)_3Ga$ )／トリメチルアルミニウム( $(CH_3)_3Al$ )／トリメチルインジウム( $(CH_3)_3In$ )／アンモニア( $NH_3$ )系減圧MOVPE法により成長させた。珪素のドーピング源として、ジシラン( $Si_2H_6$ )を約10体積ppmの濃度で含むジシラン-水素混合ガスを利用した。多相構造の発光層104の成膜温度は890℃とし、他のIII族窒化物半導体成長層103、105の成膜温度は1050℃とした。発光層104の成膜終了後、n形保護層105の成膜温度へは、アンモニア気流中で毎分約150℃の速度で昇温した。n形保護層105の成膜を終えた後は、1050℃から950℃へ毎分約50℃の速度で降温し、更に800℃へ毎分約15℃の速度で降温した。800℃から室温近傍の温度への降温は自然冷却によった。以上の昇温及び降温速度の採用により、多相構造の発光層104を構成する従属相Tのインジウム組成、外形状、並びに大きさの均一化を図った。

【0032】第1の緩衝層102aの層厚(d)は約20nmとした。第2の緩衝層102bの層厚は約2μmとし、キャリア濃度(n)は約 $2 \times 10^{18} \text{ cm}^{-3}$ とした。下部障壁層103は $d=0.5 \mu\text{m}$ とし、 $n=3 \times 10^{18} \text{ cm}^{-3}$ とした。発光層104は $d=0.1 \mu\text{m}$ とし、キャリア濃度(n)は $1 \times 10^{17} \text{ cm}^{-3}$ とした。積層構造体20を構成するn形エピタキシャル成長層102~105を成膜を終え、室温に冷却した後、MOCVD成長炉より積層構造体20を取り出した。次に、n形保護層105上に $CuAlO_2$ からなる透明p形酸化物導電層106を、一般的なマグネトロンスパッタリング法により基板101の温度を約300℃として被着させた。スパッタリング時の圧力は約0.1トール(Torr)とし、印可する高周波(RF)電力は約150ワット(W)とした。p形酸化物導電層106の層厚は約0.15μmとした。同層106の抵抗率は室温で約 $2 \Omega \cdot \text{cm}$ となった。同一条件で別途、ガラス基板上に成膜した $CuAlO_2$ 膜(膜厚=0.15μm)の波長450nmの青色帯光についての透過率は約68%であった。多相構造の発光層104を構成する主体相SをなすGaN(禁止帯幅=3.4eV)と禁止帯幅が約3.5eVの $CuAlO_2$ との禁止帯幅は約0.1eVとなった。

【0033】p形導電性酸化物層106上には、同層1

06がp形電極層をも兼用できることに鑑み、下層部107aをチタン(Ti)とし、上層部107bをAlとする重層構造からなる台座電極107を設けた。台座電極107は、直径を約140μmとする円形とした。下層のTi膜107aの膜厚は約150nmとした。上層のAl膜107bの膜厚は約1μmとした。導電性のSi基板101の裏面側の全面には、Al-Sb合金からなるn形オーミック電極108を被着させた。n形オーミック電極108の層厚は約1μmとした。

【0034】一辺を約350μmとするチップ状に分割し、個別のLED10となした。p形電極107及びn形オーミック電極108間に順方向に20ミリアンペア(mA)の電流を通流したところ、p形電極107の外周囲の領域の略全面からほぼ均一な強度をもって、青色光が放射された。分光器により測定された発光波長は約445nmであった。また、発光スペクトルの半値幅は約28nmであり、単色性に優れる発光が得られた。順方向電圧(@20mA)は平均して3.2ボルト(V)となった。チップ状態での発光強度は約22マイクロワット(μW)に到達した。

【0035】(実施例2)本実施例では、透明なp形導電性酸化物層を備えた積層構造体40から青色LED30を構成する場合を例にして、本発明を詳細に説明する。図2は本実施例に係わるLED30の断面模式図である。

【0036】積層構造体30は、(0001)サファイア基板101、GaN低温緩衝層102、Siドーパn形GaNからなるn形障壁層103、主体相Sをn形Ga<sub>0.95</sub>In<sub>0.05</sub>Nとし、平均的なインジウム組成比を0.15とする窒化ガリウム・インジウム混晶(Ga<sub>0.85</sub>In<sub>0.15</sub>N)を従属相Tとする多相構造のn形発光層104、及び $CuAlO_2$ からなる透明p形導電層106から構成した。

【0037】多結晶の緩衝層102は430℃で成膜した。低温緩衝層102以外のIII族窒化物化合物半導体層103、104は、トリメチルガリウム／トリメチルアルミニウム／シクロペンタジエニルインジウム( $C_5H_5In$ )／アンモニア系常圧MOVPE法により成長させた。多相構造の発光層104の成膜温度は880℃とし、他のIII族窒化物半導体成長層103、105の成膜温度は1030℃とした。発光層104の成膜終了後は、アンモニア気流中で毎分約15℃の速度で800℃へ降温した。800℃から室温近傍の温度への降温は自然に冷却させた。この降温操作により、多相構造の発光層104を構成する従属相Tのインジウム組成、外形状、並びに大きさの均一化を図った。珪素のドーピング源として、ジシランを約10体積ppmの濃度で含むジシラン-水素混合ガスを利用した。

【0038】緩衝層102の層厚(d)は約17nmとした。n形障壁層103は $d=0.5 \mu\text{m}$ とし、キャリ

ア濃度 ( $n$ ) =  $3 \times 10^{18} \text{ cm}^{-3}$  とした。発光層 104 は  $d = 0.1 \mu\text{m}$  とし、キャリア濃度 ( $n$ ) =  $1 \times 10^{17} \text{ cm}^{-3}$  とした。積層構造体 20 を構成する  $n$  形エピタキシャル成長層 103、104 を成膜を終え、室温に冷却した後、MOCVD 成長炉より積層構造体 20 を取り出した。次に、発光層 104 上に  $\text{CuAlO}_2$  からなる透明  $p$  形酸化物導電層 106 を、一般的なレーザーアブレーション法により基板 101 の温度を約  $300^\circ\text{C}$  とし、被着させた。被着時の圧力は約  $0.1 \text{ Torr}$  とした。 $p$  形酸化物導電層 106 の層厚は約  $0.25 \mu\text{m}$  とした。同層 106 の抵抗率は室温で約  $1 \Omega \cdot \text{cm}$  となった。同一条件で別途、ガラス基板上に成膜した  $\text{CuAlO}_2$  膜 (膜厚 =  $0.25 \mu\text{m}$ ) の波長  $450 \text{ nm}$  の青色帯光についての透過率は約  $62\%$  であった。多相構造の発光層 104 を構成する主体相 S をなす  $\text{Ga}_{0.95}\text{In}_{0.05}\text{N}$  (禁止帯幅 =  $3.3 \text{ eV}$ ) と禁止帯幅が約  $3.5 \text{ eV}$  の  $\text{CuAlO}_2$  との禁止帯幅は約  $0.2 \text{ eV}$  となった。

【0039】 $p$  形導電性酸化物層 106 上には、同層 106 が  $p$  形電極層をも兼用できることに鑑み、下層部 107a を  $\text{Ti}$  とし、上層部 107b を  $\text{Au}$  とする重層構造からなる台座電極 107 を設けた。台座電極 107 は、長辺を約  $300 \mu\text{m}$  とし、短辺を約  $120 \mu\text{m}$  とする長方形とした。下層の  $\text{Ti}$  膜 107a の膜厚は約  $150 \text{ nm}$  とした。上層の  $\text{Au}$  膜 107b の膜厚は約  $0.8 \mu\text{m}$  とした。 $n$  形オーミック電極 108 は、その形成予定領域に在る  $p$  形障壁層を兼ねる導電性酸化物層 106、多相構造の発光層 104 を  $\text{Ar}/\text{メタン} (\text{CH}_4)/\text{水素} (\text{H}_2)$  混合ガスを用いたプラズマエッチング法により除去し、露呈させた  $n$  形障壁層 103 の表層部に形成した。 $n$  形オーミック電極 108 は、 $\text{Al}$  から構成し、その層厚は約  $0.8 \mu\text{m}$  とした。 $n$  形オーミック電極 108 の平面形状は、長辺を約  $300 \mu\text{m}$  とし、短辺を約  $120 \mu\text{m}$  とする長方形とした。 $n$  形及び  $p$  形電極 107、108 は相互に対向する位置に互いに略平行に配列した。

【0040】次に、一辺を約  $350 \mu\text{m}$  とするチップ状に分割し、個別の LED 30 とした。 $p$  形電極 107 及び  $n$  形オーミック電極 108 間に順方向に  $20 \text{ mA}$  の電流を通流したところ、 $p$  形電極 107 の外周囲の領域の略全面からほぼ均一な強度をもって、青緑色光が放射

された。分光器により測定された発光波長は約  $478 \text{ nm}$  であった。また、発光スペクトルの半値幅は約  $32 \text{ nm}$  となった。順方向電圧 (@  $20 \text{ mA}$ ) は平均して  $3.1 \text{ V}$  となった。チップ状態での発光強度は約  $16 \mu\text{W}$  に到達した。

#### 【0041】

【発明の効果】本発明に依れば、発光層上に、 $p$  形障壁層、 $p$  形電極層及び  $p$  形ウィンドウ層を兼用する  $p$  形導電性を呈する透明酸化物層を設ける構成としたので、従来の如く III 族窒化物半導体から低抵抗の  $p$  形層を形成する際の煩雑な工程を要せずに、 $pn$  接合型ヘテロ接合構造の発光部が構成でき、この構成からなる発光部を利用すれば高輝度の III 族窒化物半導体発光素子が簡便に提供できる。

【0042】また、本発明に依れば、多相構造からなる発光層を構成する主体相の禁止帯幅を基準として、透明  $p$  形酸化物層を構成することとしたので、順方向電圧が低く、且つ発光面積が拡大された、高輝度の III 族窒化物半導体発光素子が提供される。

#### 【図面の簡単な説明】

【図 1】実施例 1 に記載の LED の断面模式図である。

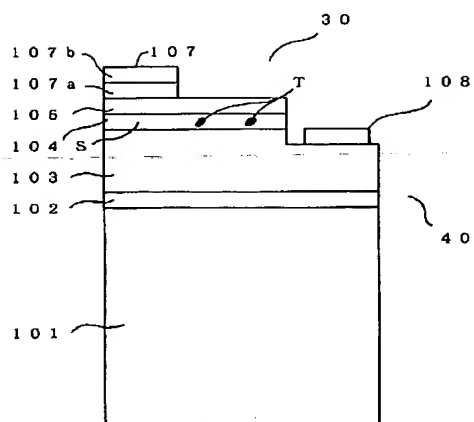
【図 2】実施例 2 に記載の LED の断面模式図である。

#### 【符号の説明】

10	LED
20	積層構造体
30	LED
40	積層構造体
101	単結晶基板
102	緩衝層
102a	第 1 の緩衝層
102b	第 2 の緩衝層
103	下部障壁層
104	発光層
105	保護層
106	透明 $p$ 形導電性酸化物膜
107	$p$ 形台座電極
107a	電極下層部
107b	電極上層部
108	$n$ 形オーミック電極
S	多相構造発光層の主体相
T	多相構造発光層の従属相



【图2】



F ターム(参考)	5F041	AA42	CA03	CA40	CA46	
	5F045	AA04	AA18	AA19	AB14	AB17
		AB18	AB40	AC01	AC08	AC09
		AC12	AC16	AC19	AD04	AD05
		AD06	AD07	AD08	AD09	AF03
		AF04	AF05	AF09	BB16	CA09
		CA10	CA11	CA12	DA51	DA52
		DA53	DA54	DA55	DA62	DA63
		DA64				
	5F073	CA07	EA05	EA24		

【公報種別】特許法第17条の2の規定による補正の掲載

【部門区分】第7部門第2区分

【発行日】平成16年7月22日(2004.7.22)

【公開番号】特開2001-53338(P2001-53338A)

【公開日】平成13年2月23日(2001.2.23)

【出願番号】特願平11-227075

【国際特許分類第7版】

H 0 1 L 33/00

H 0 1 L 21/205

H 0 1 S 5/32

【F I】

H 0 1 L 33/00 C

H 0 1 L 21/205

H 0 1 S 5/32

【手続補正書】

【提出日】平成15年6月30日(2003.6.30)

【手続補正1】

【補正対象書類名】明細書

【補正対象項目名】特許請求の範囲

【補正方法】変更

【補正の内容】

【特許請求の範囲】

【請求項1】

発光部として、n形のIII族窒化物半導体からなる障壁層と、インジウム含有III族窒化物半導体からなる発光層と、酸化物からなるp形層とを含むことを特徴とするIII族窒化物半導体発光素子。

【請求項2】

発光層が、インジウム濃度を相違する複数相のIII族窒化物半導体(多層構造発光層)から構成されていることを特徴とする請求項1に記載のIII族窒化物半導体発光素子。

【請求項3】

酸化物からなるp形層の禁止帯幅が、発光層から出射される発光波長に対応する禁止帯幅より大きいことを特徴とする請求項1または2に記載のIII族窒化物半導体発光素子。

【請求項4】

酸化物からなるp形層が、400nm～600nmの波長の発光に対して、40%以上の透過率を有することを特徴とする請求項1～3の何れか1項に記載のIII族窒化物半導体発光素子。

【請求項5】

酸化物からなるp形層の禁止帯幅が、多層構造発光層を構成する主体相の禁止帯幅以上であることを特徴とする請求項2に記載のIII族窒化物半導体発光素子。

【請求項6】

酸化物からなるp形層の禁止帯幅と、多層構造発光層を構成する主体相の禁止帯幅との差異が1.0eV以下であることを特徴とする請求項5に記載のIII族窒化物半導体発光素子。

【請求項7】

酸化物からなるp形層が、銅を含む酸化物から構成されていることを特徴とする請求項1～6の何れか1項に記載のIII族窒化物半導体発光素子。

【請求項8】

酸化物からなるp形層が、CuAlO<sub>2</sub>であることを特徴とする請求項7に記載のIII族窒化物半導体発光素子。

族窒化物半導体発光素子。

【請求項 9】

酸化物からなる p 形層の層厚が、5 nm～500 nmであることを特徴とする請求項 8 に記載の III 族窒化物半導体発光素子。

【請求項 10】

$\text{CuAlO}_2$  が、多結晶体であることを特徴とする請求項 8 または 9 に記載の III 族窒化物半導体発光素子。

【請求項 11】

酸化物からなる p 形層と発光層との間に、 $\text{Al}_x\text{Ga}_y\text{In}_z\text{N}$  ( $0 < X \leq 1$ ,  $0 \leq Y < 1$ ,  $X + Y + Z = 1$ ) で表記される III 族窒化物半導体層が備えられていることを特徴とする請求項 1～10 の何れか 1 項に記載の III 族窒化物半導体発光素子。

【請求項 12】

発光部として、n 形の III 族窒化物半導体からなる障壁層と、インジウム含有 III 族窒化物半導体からなる発光層と、酸化物からなる p 形層とを含む III 族窒化物半導体発光素子の製造方法において、酸化物からなる p 形層をスパッタリング法或いはレーザーアブレーション法により成膜することを特徴とする III 族窒化物半導体発光素子の製造方法。

【請求項 13】

酸化物からなる p 形層が、銅を含む酸化物から構成されていることを特徴とする請求項 12 に記載の III 族窒化物半導体発光素子の製造方法。

【請求項 14】

酸化物からなる p 形層が、 $\text{CuAlO}_2$  であることを特徴とする請求項 13 に記載の III 族窒化物半導体発光素子の製造方法。

【請求項 15】

請求項 1～11 の何れか 1 項に記載の III 族窒化物半導体発光素子からなる LED。

# PATENT ABSTRACTS OF JAPAN

(11)Publication number : 2001-053338

(43)Date of publication of application : 23.02.2001

(51)Int.Cl.

H01L 33/00  
H01L 21/205  
H01S 5/32

(21)Application number : 11-227075

(71)Applicant : SHOWA DENKO KK

(22)Date of filing : 11.08.1999

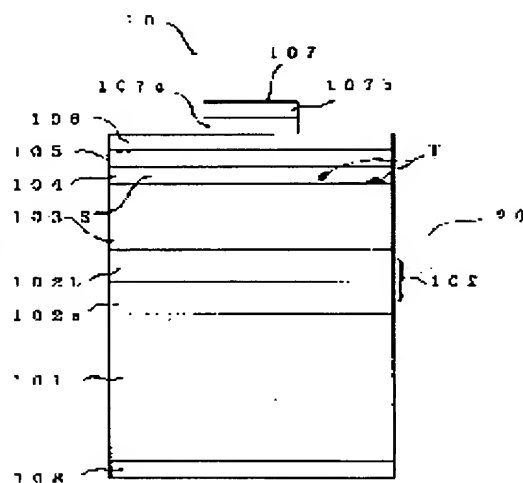
(72)Inventor : UDAGAWA TAKASHI  
MIKI HISAYUKI

## (54) III NITRIDE SEMICONDUCTOR LIGHT-EMITTING DEVICE

### (57)Abstract:

**PROBLEM TO BE SOLVED:** To constitute a light-emitting section having P-N junction type heterojunction structure without requiring a complicated process by containing a barrier layer composed of an N-type group III nitride semiconductor, a light-emitting layer comprising an indium-containing III nitride semiconductor and a P-type layer consisting of an oxide as the light-emitting section.

**SOLUTION:** A blue LED 10 is constituted of a laminated structure 20, having a transparent P-type conductive oxide layer functioning as a P-type barrier layer, a P-type window layer and a P-type electrode layer in combination. The laminated structure 20 is composed of an Sb-doped N-type Si single-crystal substrate 101 and an N-type buffer layer 103 comprising a polycrystalline N-type first buffer layer 102a, using zinc blende type cubic boron phosphide (BP) as the main body and an N-type second buffer layer 102b, using cubic BP as the main body. The light-emitting device is configured of an N-type light-emitting layer 104, having polyphase structure using a gallium-indium mixed crystal, in which main body phase S is formed of N-type GaN and an indium composition ratio is set to 0.1, as slave phase T, an undoped N-type protective layer 105 and a transparent P-type conductive layer 106 composed of CuAlO<sub>2</sub>.



**\* NOTICES \***

JPO and INPIT are not responsible for any damages caused by the use of this translation.

1.This document has been translated by computer. So the translation may not reflect the original precisely.

2.\*\*\*\* shows the word which can not be translated.

3.In the drawings, any words are not translated.

---

**CLAIMS**

---

[Claim(s)]

[Claim 1]A group III nitride semiconductor light emitting element comprising:

A barrier layer which consists of a group III nitride semiconductor of n form as a light-emitting part.

A luminous layer which consists of an indium content group III nitride semiconductor.

A p type layer which consists of oxides.

[Claim 2]The group III nitride semiconductor light emitting element according to claim 1, wherein a luminous layer comprises a group III nitride semiconductor (multilayer-structure luminous layer) of two or more phases which are different in indium concentration.

[Claim 3]The group III nitride semiconductor light emitting element according to claim 1 or 2, wherein a band gap of a p type layer which consists of oxides is larger than a band gap corresponding to a luminous wavelength emitted from a luminous layer.

[Claim 4]A group III nitride semiconductor light emitting element given in any 1 paragraph of claims 1-3, wherein a p type layer which consists of oxides has the transmissivity of not less than 40% to luminescence with a wavelength of 400 nm - 600 nm.

[Claim 5]A group III nitride semiconductor light emitting element given in any 1 paragraph of claims 2-4, wherein a band gap of a p type layer which consists of oxides is more than a band gap of a matrix phase which constitutes a multilayer-structure luminous layer.

[Claim 6]The group III nitride semiconductor light emitting element according to claim 5, wherein a difference between a band gap of a p type layer which consists of oxides, and a band gap of a matrix phase which constitutes a multilayer-structure luminous layer is 1.0 eV or less.

[Claim 7]A group III nitride semiconductor light emitting element given in any 1 paragraph of claims 1-6, wherein a p type layer which consists of oxides comprises an oxide containing copper.

[Claim 8]The group III nitride semiconductor light emitting element according to claim 7, wherein a p type layer which consists of oxides is  $\text{CuAlO}_2$ .

[Claim 9]The group III nitride semiconductor light emitting element according to claim 8, wherein thickness of a p type layer which consists of oxides is 5 nm - 500 nm.

[Claim 10]The group III nitride semiconductor light emitting element according to claim 8 or 9, wherein  $\text{CuAlO}_2$  is the polycrystalline substance.

[Claim 11]Between a p type layer and a luminous layer which consist of oxides, A group III nitride semiconductor light emitting element given in any 1 paragraph of claims 1-10, wherein it has a group III nitride semiconductor layer written by  $\text{aluminum}_X\text{Ga}_Y\text{In}_Z\text{N}$  ( $0 < X \leq 1$ ,  $0 \leq Y < 1$ ,  $X+Y+Z=1$ ).

---

[Translation done.]

## \* NOTICES \*

JPO and INPIT are not responsible for any damages caused by the use of this translation.

1. This document has been translated by computer. So the translation may not reflect the original precisely.
2. \*\*\*\* shows the word which can not be translated.
3. In the drawings, any words are not translated.

---

## DETAILED DESCRIPTION

---

[Detailed Description of the Invention]

[0001]

[Field of the Invention] It is related with the group III nitride semiconductor light emitting element provided with the light-emitting part of the pn junction type hetero structure which comprises p form conduction layers other than a group III nitride semiconductor.

[0002]

[Description of the Prior Art] The light emitting diode (LED) or laser diode (LD) which presents luminescence of the conventional blue belt or a green belt, The laminated structure body provided with the III group nitride semiconductor crystal layer which grew epitaxially on the sapphire (alpha-aluminum  $2O_3$  single crystal) board by the organic metal pyrolysis vapor-phase-epitaxy (MOCVD) method is chiefly constituted as a parent (for example). Refer to Jpn.J.Appl.Phys., Vol.34, Part2, No.10B (1995), L1332 - L 1335 pages. Sapphire is substituted and there is also conventional technology which constitutes LD from a gallium nitride (GaN) system epitaxial structure which used silicon carbide (SiC) as the substrate (refer to "applied physics", volume [ 68th ] No. 7 (1999), 797 - 800 pages). a silicon (Si) single crystal is used as a substrate, and the example which constitutes blue LED from a laminated structure body containing the aluminum nitride (AlN) which formed membranes by the molecular beam epitaxial (MBE) method is also known (Electron.Lett., Vol.33, and No.23 (1997).) Refer to 1986-1987 pages. . With the group III nitride semiconductor as used in the field of here, nitrogen (N) is included as a V fellows composing element. General formula aluminum<sub>X</sub>Ga<sub>Y</sub>In<sub>Z</sub>N (0<=X<=1, 0<=Y<1, X+Y+Z=1), He is a group III-V semiconductor written by aluminum<sub>X</sub>Ga<sub>Y</sub>In<sub>Z</sub>N<sub>1-Q</sub>M<sub>Q</sub> (0<=X<1, 0<=Y<1, X+Y+Z=1, and the sign M are the Vth group element other than nitrogen, and are 0<=Q<1).

[0003] In group III nitride semiconductor light emitting elements, such as LED or LD, gallium nitride indium (Ga<sub>X</sub>In<sub>1-X</sub> N: 0<=X<=1), Although it has a band gap suitable for emitting short wavelength visible light therefore, it is utilized as a luminous layer of a group III nitride semiconductor light emitting element (refer to JP,55-3834,B). The light-emitting part of these light emitting devices is the purpose of gaining the short wavelength visible light of high intensity, and it is common to comprise a pn junction type double hetero (DH) structure (for example, above-mentioned Jpn.J.Appl.Phys. and Vol.34 (1995) reference). A luminous layer is constituted from Ga<sub>X</sub>In<sub>1-X</sub>N (0<=X<=1) which consists of polyphase (multi-phase) structure which consists of two or more phases (phase) which are different in indium composition (=1-X). The art of obtaining a high-intensity group III nitride semiconductor light emitting element is also indicated (refer to American patent US-No. 5,886,367).

[0004] Being in conventional pn junction type DH structure, generally p form or n form barrier layer which pinches a luminous layer comprises group III nitride semiconductors, such as p form or gallium aluminum nitride (aluminum<sub>X</sub>Ga<sub>1-X</sub> N: 0<=X<=1) of n form. In order that GaN system material may present conduction of n form in the state of what is called undoped (undope) that does not add an impurity intentionally (refer to JP,53-20882,A specification), it is the common knowledge which the aluminum<sub>X</sub>Ga<sub>1-X</sub>N layer of n form tends to form. On the other hand, the aluminum<sub>X</sub>Ga<sub>1-X</sub>N layer of p form is chiefly formed with a means to dope magnesium (Mg) as p type impurities. However, Mg is electrically inactivated by the hydrogen which invades in a growth phase at the time of the membrane formation (refer to the patent No. 2872096 gazette). For this reason, it is also publicly known not to be obtained by stabilizing the p form aluminum<sub>X</sub>Ga<sub>1-X</sub>N layer of low resistance in the state of as-grown (refer to JP,61-7671,A specification).

[0005] In order to obtain the p form aluminum<sub>x</sub>Ga<sub>1-x</sub>N layer of the low resistance needed for constituting pn junction type DH structure, in the former. A means to heat-treat 400 °C at the above temperature after membrane formation is adopted to the as-grown growth phase by which the p type impurities which once formed membranes were doped (refer to patent No. 2540791). Or a means to irradiate with an electron beam under vacuum environment for the aluminum<sub>x</sub>Ga<sub>1-x</sub>N growth phase by which the p type impurities of an as-grown state were added, and to activate p type impurities electrically is taken (refer to patent No. 2500319).

[0006] In the former, the composition which takes out luminescence from the surface side of a p form III-V compound semiconductor growth phase outside is large number of people. That is, for example, it has been arranged in the upper part of a luminous layer, it has composition which takes out luminescence from the p form aluminum<sub>x</sub>Ga<sub>1-x</sub>As (0 ≤ X ≤ 1) barrier layer side outside. For this reason, if it is in GaN system LED of a conventional type, in order that the electrode provided above a top barrier layer may raise the extraction efficiency of luminescence to the exterior, it mainly comprises material of transparency or translucency. For example, the composition which provides the electrode which consists of layered structure of gold (Au) and nickel (nickel) on the transparent electrode which consists of indium oxide and tin (abbreviation: ITO), and its transparent electrode is indicated via the GaN system semiconductor layer which added p type impurities (refer to patent No. 2661009). It is known that the electrode which consists of composition which inserted nickel oxide (NiO) between Au and nickel is translucency (refer to patent No. 2916424). The contact (contact) layer which consists of p form GaN is made to intervene, and the art which arranges the zinc oxide (ZnO) layer by which aluminum (aluminum) was added as an ohmic contact layer of an Au electrode is indicated (refer to American patent US No. 5,889,295).

[0007]

[Problem(s) to be Solved by the Invention] Like the above, a means to constitute a pn junction type light-emitting part using the group III nitride semiconductor growth phase formed by the epitaxial grown method is complicated. Requiring the special processing for activating p type impurities electrically after the epitaxial growth for obtaining p form group III nitride semiconductor layer of low resistance especially is also increase of the complicated nature of a process, and a cause to which the productive efficiency of a group III nitride semiconductor light emitting element is reduced remarkably. The problem in this conventional technology is thought out with that by which solution is achieved by a means to, constitute an electron hole (hole) feed layer from material of the low resistance different from the III group nitride semiconductor crystal layer of p form which can have and form a simple means for example.

[0008] In the conventional composition which provides directly the transparent electrode which consists of transparent oxides on the group III nitride semiconductor layer by which p type impurities were doped, there is inconvenience by which good ohmic (Ohmic) contact nature is not revealed by being stabilized by the transparent oxide material and the group III nitride semiconductor layer which constitute an electrode. This originates also in the difference in the band gap of the III group nitride semiconductor crystal layer and transparent oxide electrode which constitute a light emitting device having become large extremely. For this reason, if it is in LED and is in forward voltage (what is called Vf) and LD, the problem that threshold voltage (what is called Vth) cannot be reduced effectively is produced.

[0009] The example of the measure which improves the ohmic contact nature of a transparent conductive oxide layer and an LED composition layer, It can grasp to the conventional technology about aluminium phosphide gallium indium (aluminum<sub>x</sub>Ga<sub>1-x</sub>) (YIn<sub>1-y</sub>P: 0 ≤ X ≤ 1, 0 < Y ≤ 1) LED. For example, after inserting gallium arsenide (GaAs),  $\delta$ -GaAs, gallium phosphide (GaAsP), etc. as a contact layer which expects improvement in ohmic contact nature, the transparent oxide layer is made to stratify in the invention indicated to JP,11-17220,A. In the invention indicated to JP,11-4020,A, AlGaInP system LED which consists of composition which arranges uniformly a zinc (Zn) film or an Au-Zn alloy film all over p form compound semiconductor layers directly under a transparent oxide layer, such as ITO and ZnO, is indicated.

[0010] However, if the above-mentioned conventional technology concerning AlGaInP system LED which emits luminescence of a red lamp color or a yellow zone is simply diverted more to the blue of short wavelength, or the group III nitride semiconductor light emitting element of a green zone, the inconvenience to which the transmission efficiency of luminescence to the exterior is reduced will be produced. In the above-mentioned metal membrane, still more, a contact layer is constituted, for example, also by GaAs, since it is small compared with the band gap to which a band gap  $\delta$  in blue glow or



green light, luminescence will be absorbed. Namely, a means to arrange a metal membrane in order to make good ohmic contact nature with a transparent oxide layer, A conventional means to arrange the electrode formation (contact) layer which consists of a semiconductor material made smaller than the band gap converted from the wavelength of luminescence which should be penetrated cannot fully be applied to a high-intensity group III nitride semiconductor light emitting element.

[0011] Sufficient performance to penetrate luminescence of the short wavelength emitted from a  $\text{Ga}_x\text{In}_{1-x}\text{N}$  ( $0 \leq x \leq 1$ ) luminous layer is had and combined, and, in the case of group III nitride semiconductor material, it is a different transparent material of p form of low resistance, If the light-emitting part of pn junction type heterojunction structure is constituted, a high-intensity group III nitride semiconductor light emitting element can be provided. If it is the material which manifests itself good ohmic contact nature with the group III nitride semiconductor composition layer which constitutes a group III nitride semiconductor light emitting element, it will become still more convenient gaining a high-intensity group III nitride semiconductor light emitting element. The composition in which such a demand is satisfied has not come [ however, ] to be indicated in the actual condition. Especially about the luminous layer which consists of  $\text{Ga}_x\text{In}_{1-x}\text{N}$  ( $0 \leq x \leq 1$ ) of polyphase structure by which bringing about luminescence of high intensity is known, (Refer to British patent GB2316226B), The requirements for revealing the transparent conductive material of p form which is excellent in the permeability of luminescence, and the good ohmic contact characteristic are strange.

[0012] this invention having conquered the technical problem which the above-mentioned conventional technology holds, having been made for the purpose of being stabilized and providing a high-intensity group III nitride semiconductor light emitting element simple, and, Since the light-emitting part of a pn junction type hetero structure is especially constituted using the conduction layer of p form which can be formed easily, indispensable requirements are shown on the basis of the band gap of a luminous layer.

[0013]

[Means for Solving the Problem] An artificer reached this invention, as a result of carrying out efforts examination wholeheartedly that the above-mentioned technical problem should be solved. Namely, a barrier layer which this invention becomes from a group III nitride semiconductor of n form as [1] light-emitting part, A group III nitride semiconductor light emitting element containing a luminous layer which consists of an indium content group III nitride semiconductor, and a p type layer which consists of oxides, [2] A group III nitride semiconductor light emitting element given in [1], wherein a luminous layer comprises a group III nitride semiconductor (multilayer-structure luminous layer) of two or more phases which are different in indium concentration, [3] [1], wherein a band gap of a p type layer which consists of oxides is larger than a band gap corresponding to a luminous wavelength emitted from a luminous layer, or a group III nitride semiconductor light emitting element given in [2], [4] A p type layer which consists of oxides receives luminescence with a wavelength of 400 nm – 600 nm, A group III nitride semiconductor light emitting element given in any 1 paragraph of [1] – [3] having the transmissivity of not less than 40%, [5] A band gap of a p type layer which consists of a group III nitride semiconductor light emitting element given in any 1 paragraph of – [4] and [2] [6] oxide, wherein a band gap of a p type layer which consists of oxides is more than a band gap of a matrix phase which constitutes a multilayer-structure luminous layer, A group III nitride semiconductor light emitting element given in [5], wherein a difference with a band gap of a matrix phase which constitutes a multilayer-structure luminous layer is 1.0 eV or less, [7] A group III nitride semiconductor light emitting element given in any 1 paragraph of [1] – [6], wherein a p type layer which consists of oxides comprises an oxide containing copper, [8] A group III nitride semiconductor light emitting element given in [7], wherein a p type layer which consists of oxides is  $\text{CuAlO}_2$ , [9] A group III nitride semiconductor light emitting element given in [8], wherein thickness of a p type layer which consists of oxides is 5 nm – 500 nm, [10]  $\text{CuAlO}_2$  between a p type layer and a luminous layer which are set to [8] being the polycrystalline substance or [9] from a group III nitride semiconductor light emitting element of a statement, and [11] oxides, It is related with any 1 paragraph of [1] – [10], wherein it has a group III nitride semiconductor layer written by  $\text{Alumina}_x\text{Ga}_y\text{In}_z\text{N}$  ( $0 < x \leq 1$ ,  $0 \leq y < 1$ ,  $x+y+z=1$ ), without a group III nitride semiconductor light emitting element of a statement.

[0014]

[Embodiment of the Invention] The feature in a 1st embodiment of this invention is not from p form group III nitride semiconductor material about the p type layer which constitutes the light-emitting part of pn junction type heterojunction structure, and there is in constituting from an oxide material which presents

the conductivity of p form. as an oxide material -- copper oxide ( $\text{Cu}_2\text{O}$ ), and lanthanum trioxide strontium and copper ( $\text{La}_{2-x}\text{Sr}_x\text{CuO}_4$ ;  $x=1$  or  $2$ ) (Mat.Res.Soc.Symp.Proc. and Vol.156 (1989).) It can constitute from perovskite crystals, such as refer to the 183-188 page. Lanthanum trioxide calcium rhodium ( $\text{La}_{1-x}\text{Ca}_x\text{RhO}_3$ ), Superconductivity oxide materials ("physical-properties science selected-books .), such as lanthanum trioxide strontium rhodium ( $\text{La}_{1-x}\text{Sr}_x\text{RhO}_3$ ) and lanthanum trioxide barium rhodium ( $\text{La}_{1-x}\text{Ba}_x\text{RhO}_3$ ) It can constitute also from an electroconductive oxide (revised edition)" (Shokabo Publishing Co., Ltd., August 10, 1997 issue, the 6th edition of revision), and refer to the 29 page.

[0015]The band gap corresponding to the wavelength of luminescence emitted from the luminous layer which consists of an n form or  $\text{Ga}_x\text{In}_{1-x}\text{N}$  ( $0 \leq x \leq 1$ ) of p form is exceeded, And the transparence p type electrode layer which makes the barrier layer of p form serve a double purpose can be constituted from an oxide material of p form conductivity which has a band gap exceeding the band gap of a luminous layer, and it is desirable. That is, if it depends on this invention, a p type barrier layer is constituted from group III nitride semiconductor material, the complicatedness of the conventional technology which needs a tail end process after membrane formation can be avoided, and the light-emitting part of the pn junction hetero structure where the transparent electrode layer which makes \*\*\*\* and a barrier (clad) function serve a double purpose was provided can be constituted. A pn junction hetero light-emitting part is a hetero structure which pinches n form or the single luminous layer of p form by the barrier layer of both p form and n form, or is single or a pn junction type hetero light-emitting part which pinches multiple quantum well structure. For example, there is composition of the pn junction type light-emitting part which consists of an n form  $\text{Ga}_x\text{In}_{1-x}\text{N}$  ( $0 \leq x \leq 1$ ) well layer and n form aluminum  $\text{Ga}_{1-x}\text{N}$  ( $0 \leq x \leq 1$ ) barrier layer n forms. It is contained in a 1st embodiment even if it is any of a well layer or a barrier layer to be in the luminous layer of quantum well structure, and to make it join to n form and a p type barrier layer.

[0016]If a luminous layer is constituted from a group III nitride semiconductor of the polyphase structure which is different in indium concentration, luminescence of high intensity will be brought about, and if especially a group III nitride semiconductor is set to  $\text{Ga}_x\text{In}_{1-x}\text{N}$  ( $0 \leq x \leq 1$ ), a more suitable luminous layer can consist of a 2nd embodiment of this invention.

[0017]The matrix phase (matrix-phase) which specifically [ polyphase structure ] occupies most luminous layers in volume, Although volume occupied from a matrix phase is made small, it is an internal crystalline-structure structure which comprises a subordinate phase (sub-phase) which makes indium composition (concentration) larger than a matrix phase (refer to JP,10-56202,A specification). A subordinate phase usually exists as a micro crystallite object which are scattered in a matrix phase. In order to be for example, an approximate sphere form about shape and to make the diameter uniform, It can attain with regulation of the heating rate in the temperature up or temperature fall, and cooling cycle which the luminous layer concerned wears after the end of membrane formation of a  $\text{Ga}_x\text{In}_{1-x}\text{N}$  ( $0 \leq x \leq 1$ ) luminous layer, or a cooling rate (refer to above British patent GB2316226B). If it has composition which combined the oxide layer of p form conductivity with the luminous layer which has such internal crystalline-structure composition, there is an advantage which the light-emitting part of the pn junction type hetero structure of bringing about luminescence of high intensity can constitute simple.

[0018]In a 3rd embodiment of this invention, when constituted from material of the band gap exceeding the band gap which \*\*\*\*\* p form oxide layer in the luminous wavelength from a luminous layer regardless of the internal crystalline structure of a luminous layer, p form oxide layer which serves also as the transmission layer (window (window) layer) of luminescence to the exterior can be constituted, and it is convenience. If it is preferably made higher [ about 0.1 - 0.3 electron volt (unit: eV) of abbreviation ] than the band gap (band-gap) of a luminous layer, also when penetrating luminescence, and also when p form oxide layer demonstrates a barrier operation, it becomes convenient. p form oxide which demonstrates the transmissivity of not less than 40% can be used especially suitably to obtain high-intensity LED especially about luminescence which makes it the wavelength emitted from an indium content group III nitride semiconductor luminous layer, and is in the range of 400 nm - 600 nm so that it may describe in a 4th embodiment. As transmissivity is high, it is more convenient for obtaining high-intensity LED. The extraction efficiency of luminescence to the exterior gets worse rapidly with transmissivity being less than 40%.

[0019]It is in  $\text{Ga}_x\text{In}_{1-x}\text{N}$  ( $0 \leq x \leq 1$ ), and a band gap will become small if an indium composition ratio

becomes large (refer to above-mentioned JP,55-3834,B). Therefore, for example, it is in the luminous layer which consists of  $\text{Ga}_x\text{In}_{1-x}\text{N}$  ( $0 \leq x \leq 1$ ) of polyphase structure, The band gap of  $\text{Ga}_{x1}\text{In}_{1-x1}\text{N}$  ( $0 < x1 < 1$ ) which constitutes a subordinate phase is smallness from it of  $\text{Ga}_{x2}\text{In}_{1-x2}\text{N}$  ( $0 \leq x2 < x1 < 1$ ) which makes a matrix phase. The oxide material which makes a band gap larger than it on the basis of a subordinate phase was chosen, and it does not necessarily exceed the band gap of a matrix phase. Since "falling" with potential conducting zone or valence band will occur in the joining interface of a polyphase structure luminous layer and p form oxide layer if p form oxide layer of the band gap which is less than a matrix phase by making a band gap large rather than a subordinate phase is joined, The cladding (cladding) operation exerted on a career (carrier) becomes weak, and it becomes less enough "a career shut up" up in a luminous layer. Therefore, it becomes inconvenient obtaining luminescence of high intensity.

Therefore, at a 5th embodiment, p form oxide layer at the time of using the luminous layer of the polyphase structure which consists of an ingredient which is different in a band gap consists of oxide materials which make a band gap larger than it on the basis of the band gap of a matrix phase.

[0020]However, if the potential barrier of p form oxide layer and a luminous layer is superfluously expensive, although the effect "which luminescence shuts up" will be demonstrated, circulation of a career (carrier) is checked, and if spread, the inconvenience which raises  $V_f$  or  $V_{th}$  to \*\* arises.

Therefore, at a 6th embodiment, the difference of the band gap of p form oxide layer and the band gap of the matrix phase of a luminous layer shall consist of materials which carry out 1.0 eV the following.

[0021]If the oxide crystal which contains copper (Cu) as a composing element is generally compared with other oxide crystals, the oxide which gives low (small) resistance will be obtained so that it may describe in a 7th embodiment. Therefore, p form oxide crystal layer which uses copper as a composing element can be used with sufficient convenience by constituting the pn junction light-emitting part of the embodiment of this invention.  $\text{Cu}_2\text{O}$ , and the aluminum oxide and copper ( $\text{CuAlO}_2$ ) of the above [ oxide crystal ] which use copper as a composing element, There are delafossite (delafossite) crystal forms ( $\text{CuMO}_2$ :M is a trivalent metal ion), such as strontium oxide and copper ( $\text{CuSrO}_2$ ), gallium oxide, copper ( $\text{CuGaO}_2$ ).

[0022]Especially  $\text{CuAlO}_2$  by the general sputtering (sputtering) method or the laser abrasion (laser ablation) method. Resistivity is used and the low resistance p type crystal layer of 1 ohm-cm can form membranes simple (refer to "Nature", Vol.389, No.6654 (1997), 939 - 942 pages). Therefore, from  $\text{CuAlO}_2$ , the advantage from which p form oxide layer which is sufficient for constituting p form electrode layer at \*\*\*\*\* is obtained is about the complicated post process for low-resistance-izing separately after membrane formation.  $\text{CuAlO}_2$  is a transparent conductive crystal which sets a band gap to about 3.5 eV at a room temperature (above "Nature", Vol.389 reference). Therefore, sufficient luminescence transmission layer (window layer) to penetrate luminescence of a near-ultraviolet zone to the green zone emitted from a  $\text{Ga}_x\text{In}_{1-x}\text{N}$  ( $0 \leq x \leq 1$ ) luminous layer can consist of  $\text{CuAlO}_2$ . The difference in a band gap with GaN which sets a band gap to about 3.4 eV is set to about 0.1 eV. Therefore, the oxide layer joinable with the moderate barrier height which is transparent and has the conductivity of p form comprises  $\text{CuAlO}_2$ , for example to the  $\text{Ga}_x\text{In}_{1-x}\text{N}$  ( $0 \leq x \leq 1$ ) luminous layer of the polyphase structure made into a matrix phase in GaN. According to this, therefore an 8th embodiment, it makes it suitable to constitute p form oxide layer from  $\text{CuAlO}_2$ .

[0023]According to a 9th embodiment, the thickness of  $\text{CuAlO}_2$  is preferably set as not less than 5 nm. It is because it does not come to cover the whole surface of the surface of a luminous layer with less than 5 nm uniformly. It is in this invention used as an electron hole feed layer by making  $\text{CuAlO}_2$  of p form into a p type barrier layer, and an electron hole cannot fully be supplied to a luminous layer as thickness is smallness. On the other hand, if it is the thickness over 500 nm, unevenness of the surface of a p form  $\text{CuAlO}_2$  layer will become remarkable, and the extraction efficiency to the exterior of luminescence will fall notably for the scattered reflection in the surface of a same layer. Therefore, the thickness of a p form  $\text{CuAlO}_2$  layer is restricted to 500 nm at the maximum. When depending on sputtering process or a laser ablation method and forming a p form  $\text{CuAlO}_2$  layer, the thickness of a same layer can be controlled with adjusting membrane formation time.

[0024]Cu which constitutes  $\text{CuAlO}_2$  is an easily diffusive element, and the case where it spreads and invades in the luminous layer which consists of group III nitride semiconductors is possible. Copper serves

as a luminescence center (color center) with group III nitride semiconductors, such as GaN (J. refer to Appl.Phys., Vol.47, No.12 (1976), and 5387-5390 pages). Therefore, luminescence which is excellent in monochromaticity consists is hard to be obtained of a group III nitride semiconductor luminous layer which copper mixed. This invention constitutes a p form  $\text{CuAlO}_2$  crystal layer from a polycrystalline layer so that it may describe in a 9th embodiment. If it is considered as the polycrystalline substance, many grain boundaries can be made inherent in it. If many grain boundaries are made to exist, a lot of copper is caught by the grain boundary, and the diffusion to a luminous layer can be controlled so much. For example, in order to form the p form  $\text{CuAlO}_2$  crystal layer of polycrystal by the argon (Ar) SUPARRINGU method, generally making forming temperature into the range of about 500 \*\* from a room temperature is recommended. It can be checked with the analyzing method, an electron diffraction method, etc. whether there is any formed p form  $\text{CuAlO}_2$  crystal layer with polycrystal.

[0025]In order to deter more effectively diffusion into the group III nitride semiconductor luminous layer of the composing element of p form oxide layer, or a dross inclusion, and invasion, as shown in a 10th embodiment, it becomes effective in the middle of a luminous layer and p form oxide layer to arrange the group III nitride semiconductor layer containing aluminum. Since aluminum is easy-oxidizability, the group III nitride semiconductor layer containing aluminum captures the oxygen which is isolated from the upper oxide layer, and spreads and invades into a luminous layer, and becomes effective also in controlling that a luminous layer oxidizes. The group III nitride semiconductor which contains aluminum as a composing element has an effect which a band gap is generally size, therefore can be taken out from the matrix phase which constitutes an indium content group III nitride semiconductor luminous layer to the exterior without absorbing most luminescence from a luminous layer.

[0026]aluminum content group III nitride semiconductor layer provided on a luminous layer becomes useful also as a protective layer which protects a luminous layer from the damage at the time of making p form oxide layer laminate by sputtering process on it again. About, the thickness of aluminum content group III nitride semiconductor layer which becomes effective in reducing the concentration of Cu which invades into a luminous layer, or oxygen (O), and controlling damage to a luminous layer exceeds 1 nm, and the range of it is about 100 nm or less. Are in a group III nitride semiconductor light emitting element, and aluminum content group III nitride semiconductor layer, It is preferred that it is a low carrier concentration layer which sets thickness to 50 nm or less at not less than 2 nm so that it may depend on the tunnel (tunnel) effect efficiently and the electron hole (hole) supplied from p form oxide layer as an electron hole feed layer can be poured in to a luminous layer.

[0027]The Al composition ratio of aluminum content group III nitride semiconductor layer has the effect of giving change to the wavelength of luminescence emitted from a luminous layer. For example, when the crystal layer which consists of gallium aluminum nitride ( $\text{aluminum}_x\text{Ga}_{1-x}\text{N}$ ;  $0 \leq x \leq 1$ ) is made into the above-mentioned protective layer or a diffusion prevention layer, the wavelength of luminescence emitted from the luminous layer of the same specification turns into long wavelength from the increase in an aluminum composition ratio ( $=x$ ). For example, a luminous wavelength when the same  $\text{Ga}_{0.88}\text{In}_{0.12}\text{N}$  luminous layer of thickness is entitled the  $\text{aluminum}_{0.85}\text{Ga}_{0.15}\text{N}$  layer which sets thickness to about 20 nm, It is set to about 510 to about 530 nm when the  $\text{aluminum}_{0.20}\text{Ga}_{0.80}\text{N}$  layer which sets thickness to about 20 nm is made to laminate to being set to about 450 nm - about 460 nm. It is in the tendency for luminescence of long wavelength to be concluded, so that the thickness of a luminous layer is small, when an  $\text{aluminum}_x\text{Ga}_{1-x}\text{N}$  ( $0 \leq x \leq 1$ ) layer is incidentally entitled. This has suggested that a luminous wavelength is changed by the size of distortion which a luminous layer wears between an  $\text{aluminum}_x\text{Ga}_{1-x}\text{N}$  layer and a  $\text{Ga}_x\text{In}_{1-x}\text{N}$  luminous layer. However, when an aluminum composition ratio is too high, a band gap is good for becoming large and carrying out light transmission of the luminescence, but it may become a conduction resistor of element operating current. So, as for the aluminum composition ratio of an aluminum content group III nitride semiconductor, it is preferred to use that it is high with about 0.25 - about 0.30 range.

[0028]The light emitting device concerning this invention makes p form pedestal electrode laminate on p form oxide layer in the 1-10th above-mentioned embodiments, and is constituted. Since p form oxide layer of this invention is a conductive layer which can diffuse element operating current horizontally, like conventional technology, it does not need to dare to provide the metal tunic which worsens permeability like Au-nickel or Au-NiO-Au in the surface of p form group III nitride semiconductor layer, and does not

need to achieve current diffusion. When p form electrode layer is constituted from an oxide layer of p form conductivity, the pedestal electrode which is excellent in ohmic contact nature may be formed. p form pedestal electrode can consist of suitably publicly known nickel, NiO, an Au-Zn alloy, an Au-beryllium (Be) alloy, an In-Zn alloy, etc. On the other hand, the ohmic electrode of n form can consist of nickel, NiO, In, antimony (Sb), antimony oxide, an Au-germanium alloy, an Au-tin (Sn) alloy, and an In-Sn alloy, for example. In the case where conductive crystals, such as silicon (Si), SiC, or gallium phosphide (GaP), are used as a substrate, it can provide in the rear-face side of a substrate, and is convenience.

[0029]

[Example](Example 1) By this example, the case where the blue LED 10 is constituted from the laminated structure body 20 provided with transparent p form conductive oxide layer which serves both as a p type barrier layer, p form window layer, and p form electrode layer (contact layer) is made into an example, and this invention is explained in detail. Drawing-1 is a cross-section of LED10 concerning this example.

[0030]The laminated structure body 20, Sb dope n type Si single crystal substrate 101 and sphalerite type cubic Lynn-ized boron (BP) are made into a subject. The n form buffer layer 102 which consists cubic BP formed at the elevated temperature from the 1st becoming buffer layer 102a and buffer layer 102a of n form of polycrystal of the 2nd buffer layer 102b of n form that becomes as a subject, the lower barrier layer 103 which consists of Si-dope n type GaN, and the matrix phase S are set to n form GaN, An average indium composition ratio. The gallium nitride indium mix crystal set to 0.1. ( $\text{Ga}_{0.9}\text{In}_{0.1}\text{N}$ ) consisted of the transparence p type conductive layers 106 which consist of the n form luminous layer 104, the protective layer 105 which is undoped and consists of aluminum<sub>0.8</sub>Ga<sub>0.2</sub>N of n form, and  $\text{CuAlO}_2$  of the polyphase structure made into the subordinate phase T.

[0031]The 1st and 2nd buffer layers 102a and 102b made boron triethyl ( $\text{C}_2\text{H}_5$ )<sub>3</sub>B the source of boron (B), and formed membranes by the MOCVD method which makes phosphine ( $\text{PH}_3$ ) the source of Lynn (P).

The 1st buffer layer 102a of polycrystal formed membranes at 420 \*\*, in the atmosphere containing phosphine, it carried out temperature up of the temperature of the substrate 101 to 1050 \*\*, and the 2nd buffer layer 102b of the single crystal formed it, after ending membrane formation of the 1st buffer layer 102a. Each class of the epitaxial composition layers 102-105, It was made to grow up by trimethylgallium ( $\text{CH}_3$ )<sub>3</sub>Ga / trimethylaluminum ( $\text{CH}_3$ )<sub>3</sub>aluminum / trimethylindium ( $\text{CH}_3$ )<sub>3</sub>In / the ammonia ( $\text{NH}_3$ ) system decompression MO-VPE method. As a source of doping of silicon, the disilane hydrogen mixed gas which contains a disilane ( $\text{Si}_2\text{H}_6$ ) by the concentration of about 10 volume ppm was used. The forming temperature of the luminous layer 104 of polyphase structure was 890 \*\*, and the forming temperature of other group III nitride semiconductor growth phases 103 and 105 was 1050 \*\*. To the forming temperature of the n form protective layer 105, temperature up was carried out at the speed of about 150 \*\*/m in the ammonia air current after the end of membrane formation of the luminous layer 104. After finishing membrane formation of the n form protective layer 105, the temperature was lowered at the speed of about 50 \*\*/m from 1050 \*\* to 950 \*\*, and also was lowered at the speed of about 15 \*\*/m to 800 \*\*. The temperature fall to the temperature near the room temperature from 800 \*\* was based on natural air cooling. By the above temperature up and adoption of the temperature falling speed, equalization of the indium composition of the subordinate phase T which constitutes the luminous layer 104 of polyphase structure, outline shape, and a size was attained.

[0032]The thickness (d) of the 1st buffer layer 102a could be about 20 nm. The thickness of the 2nd buffer layer 102b set to about 2 micrometers, and carrier concentration (n) was made into abbreviation  $2 \times 10^{18} \text{cm}^{-3}$ . The lower barrier layer 103 set to d= 0.5 micrometer, and was taken as  $n=3 \times 10^{18} \text{cm}^{-3}$ . The luminous layer 104 set to d= 0.1 micrometer, and was taken as carrier concentration (n)  $=1 \times 10^{17} \text{cm}^{-3}$ . After finishing membrane formation and cooling the n form epitaxial growth layers 102-105 which constitute the laminated structure body 20 to a room temperature, the laminated structure body 20 was taken out from the MOCVD growth oven. Next, the temperature of the substrate 101 was made to laminate the transparence p type oxide conductive layer 106 which consists of  $\text{CuAlO}_2$  on the n form protective layer 105 as about 300 \*\* with general magnetron sputtering method. The pressure at the time of sputtering was about 0.1 torr (Torr), and the high frequency (RF) electric power which carries out a seal of approval was about 150 W (W). The thickness of the p form oxide conductive layer 106 could be about 0.15 micrometer. The resistivity of the same layer 106 became about 2 ohm-cm at the room temperature. The transmissivity about blue belt light with a wavelength of 450 nm of the  $\text{CuAlO}_2$  film (thickness = 0.15

micrometer) which formed membranes on the glass substrate separately on the same conditions was about 68%. The band gap of GaN (band gap = 3.4 eV) which makes the matrix phase S which constitutes the luminous layer 104 of polyphase structure, and  $\text{CuAlO}_2$  whose band gap is about 3.5 eV was set to about 0.1 eV.

[0033] On the p form conductive oxide layer 106, in view of the ability of the same layer 106 to also make p form electrode layer serve a double purpose, the lower layer part 107a was used as titanium (Ti), and the pedestal electrode 107 which consists of layered structure which sets the upper levels 107b to aluminum was formed. The pedestal electrode 107 was made into the round shape which shall be about 140 micrometers in diameter. The thickness of lower layer Ti film 107a could be about 150 nm. The thickness of upper Al film 107b could be about 1 micrometer. The n form ohmic electrode 108 which consists of an aluminum-Sb alloy was made to laminate all over the rear-face side of conductive Si substrate 101. The thickness of the n form ohmic electrode 108 could be about 1 micrometer.

[0034] It divided into the chip shape which sets one side to about 350 micrometers, and made with individual LED10. Between the p form electrode 107 and the n form ohmic electrode 108, when conduction of the current of 20 mA (mA) was carried out to the forward direction, it had almost uniform intensity from the approximately whole area of the field of the peripheral wall of the p form electrode 107, and blue glow was emitted. The luminous wavelength measured by the spectroscope was about 445 nm. The half breadth of an emission spectrum is about 28 nm, and luminescence which is excellent in monochromaticity was obtained. Forward voltage (@20mA) was averaged and became 3.2-volt (V). The luminescence intensity in the chip state reached about 22 microwatts (microwatt).

[0035] (Example 2) By this example, the case where the blue LED 30 is constituted from the laminated structure body 40 provided with transparent p form conductive oxide layer is made into an example, and this invention is explained in detail. Drawing 2 is a cross section of LED30 concerning this example.

[0036] The laminated structure body 30 sets to n form  $\text{Ga}_{0.95}\text{In}_{0.05}\text{N}$  the silicon on sapphire (0001) 101, the GaN low temperature buffer layer 102, the n form barrier layer 103 that consists of Si-dope n type GaN, and the matrix phase S, The gallium nitride indium mix crystal ( $\text{Ga}_{0.85}\text{In}_{0.15}\text{N}$ ) which sets an average indium composition ratio to 0.15 consisted of the n form luminous layer 104 of the polyphase structure made into the subordinate phase T, and the transparency p type conductive layer 106 which consists of  $\text{CuAlO}_2$ .

[0037] The buffer layer 102 of polycrystal formed membranes at 430 \*\*. III fellows nitriding \*\*\*\* semiconductor layers 103, 104 other than low temperature buffer layer 102 were grown up by trimethylgallium / trimethylaluminum / cyclopentadienyl indium ( $\text{C}_5\text{H}_5\text{In}$ ) / the ammonia system ordinary pressure MO-VPE method. The forming temperature of the luminous layer 104 of polyphase structure was 880 \*\*, and the forming temperature of other group III nitride semiconductor growth phases 103 and 105 was 1030 \*\*. After the end of membrane formation of the luminous layer 104 was lowered to 800 \*\* at the speed of about 15 \*\*/m in the ammonia air current. The temperature fall to the temperature near the room temperature from 800 \*\* was made to cool automatically. By this temperature fall operation, equalization of the indium composition of the subordinate phase T which constitutes the luminous layer 104 of polyphase structure, outline shape, and a size was attained. As a source of doping of silicon, the disilane hydrogen mixed gas which contains a disilane by the concentration of about 10 volume ppm was used.

[0038] The thickness (d) of the buffer layer 102 could be about 17 nm. The n form barrier layer 103 set to  $d = 0.5$  micrometer, and was taken as carrier concentration ( $n$ ) =  $3 \times 10^{18} \text{ cm}^{-3}$ . The luminous layer 104 set to  $d = 0.1$  micrometer, and was taken as carrier concentration ( $n$ ) =  $1 \times 10^{17} \text{ cm}^{-3}$ . After finishing membrane formation and cooling the n form epitaxial growth layers 103 and 104 which constitute the laminated structure body 20 to a room temperature, the laminated structure body 20 was taken out from the MOCVD growth oven. Next, the temperature of the substrate 101 was made to laminate the transparency p type oxide conductive layer 106 which consists of  $\text{CuAlO}_2$  on the luminous layer 104 as about 300 \*\* with a general laser ablation method. The pressure at the time of covering was set to about 0.1 Torr(s). The thickness of the p form oxide conductive layer 106 could be about 0.25 micrometer. The resistivity of the same layer 106 became about 1 ohm-cm at the room temperature. The transmissivity about blue belt light with a wavelength of 450 nm of the  $\text{CuAlO}_2$  film (thickness = 0.25 micrometer) which formed

membranes on the glass substrate separately on the same conditions was about 62%. The band gap of  $\text{Ga}_{0.95}\text{In}_{0.05}\text{N}$  (band gap = 3.3 eV) which makes the matrix phase S which constitutes the luminous layer



104 of polyphase structure, and  $\text{CuAlO}_2$  whose band gap is about 3.5 eV was set to about 0.2 eV.

[0039] On the p form conductive oxide layer 106, in view of the ability of the same layer 106 to also make p form electrode layer serve a double purpose, the lower layer part 107a was set to Ti, and the pedestal electrode 107 which consists of layered structure which sets the upper levels 107b to Au was formed. The pedestal electrode 107 set the long side to about 300 micrometers, and made it the rectangle which sets a shorter side to about 120 micrometers. The thickness of lower layer Ti film 107a could be about 150 nm. The thickness of upper Au membrane 107b could be about 0.8 micrometer. The n form ohmic electrode 108 removes the conductive oxide layer 106 which serves as the p type barrier layer in the formation scheduled region, and the luminous layer 104 of polyphase structure by the plasma etching technique using Ar / methane ( $\text{CH}_4$ ) / hydrogen ( $\text{H}_2$ ) mixed gas, It formed in the layer part of the n form barrier layer 103 made to expose. The n form ohmic electrode 108 was constituted from aluminum, and the thickness set it to about 0.8 micrometer. The plane shape of the n form ohmic electrode 108 set the long side to about 300 micrometers, and made it the rectangle which sets a shorter side to about 120 micrometers. n form and the p form electrodes 107 and 108 of each other [ the position which counters mutually ] were arranged to abbreviated parallel.

[0040] Next, it divided into the chip shape which sets one side to about 350 micrometers, and made with individual LED30. Between the p form electrode 107 and the n form ohmic electrode 108, when conduction of the 20-mA current was carried out to the forward direction, it had almost uniform intensity from the approximately whole area of the field of the peripheral wall of the p form electrode 107, and blue-green light was emitted. The luminous wavelength measured by the spectroscope was about 478 nm. The half breadth of the emission spectrum was set to about 32 nm. Forward voltage (@20mA) was averaged and was set to 3.1V. The luminescence intensity in the chip state reached about 16 microwatts.

[0041]

[Effect of the Invention] Since it had composition which provides the transparent oxide layer which presents p form conductivity which makes a p type barrier layer, p form electrode layer, and p form window layer serve a double purpose on a luminous layer when depending on this invention, The light-emitting part of pn junction type heterojunction structure can be constituted from a group III nitride semiconductor like the former, without requiring the complicated process at the time of forming the p type layer of low resistance, and if the light-emitting part which consists of this composition is used, a high-intensity group III nitride semiconductor light emitting element can provide simple.

[0042] When depending on this invention, since a transparence p type oxide layer is constituted on the basis of the band gap of the matrix phase which constitutes the luminous layer which consists of polyphase structures, forward voltage is low and the high-intensity group III nitride semiconductor light emitting element to which the emission area was expanded is provided.

---

[Translation done.]



**\* NOTICES \***

JPO and INPIT are not responsible for any damages caused by the use of this translation.

- 1.This document has been translated by computer. So the translation may not reflect the original precisely.
- 2.\*\*\*\* shows the word which can not be translated.
- 3.In the drawings, any words are not translated.

---

**TECHNICAL FIELD**

[Field of the Invention]It is related with the group III nitride semiconductor light emitting element provided with the light-emitting part of the pn junction type hetero structure which comprises p form conduction layers other than a group III nitride semiconductor.

---

[Translation done.]

\* NOTICES \*

JPO and INPIT are not responsible for any damages caused by the use of this translation.

1. This document has been translated by computer. So the translation may not reflect the original precisely.
2. \*\*\*\* shows the word which can not be translated.
3. In the drawings, any words are not translated.

---

PRIOR ART

---

[Description of the Prior Art] The light emitting diode (LED) or laser diode (LD) which presents luminescence of the conventional blue belt or a green belt, The laminated structure body provided with the III group nitride semiconductor crystal layer which grew epitaxially on the sapphire (alpha-aluminum  $2O_3$  single crystal) board by the organic metal pyrolysis vapor-phase-epitaxy (MOCVD) method is chiefly constituted as a parent (for example). Refer to Jpn.J.Appl.Phys., Vol.34, Part2, No.10B (1995), L1332 - L 1335 pages. Sapphire is substituted and there is also conventional technology which constitutes LD from a gallium nitride (GaN) system epitaxial structure which used silicon carbide (SiC) as the substrate (refer to "applied physics", volume [ 68th ] No. 7 (1999), 797 - 800 pages). a silicon (Si) single crystal is used as a substrate, and the example which constitutes blue LED from a laminated structure body containing the aluminum nitride (AlN) which formed membranes by the molecular beam epitaxial (MBE) method is also known (Electron.Lett., Vol.33, and No.23 (1997).) Refer to 1986-1987 pages. . With the group III nitride semiconductor as used in the field of here, nitrogen (N) is included as a V fellows composing element. General formula aluminum<sub>X</sub>Ga<sub>Y</sub>In<sub>Z</sub>N (0<=X<=1, 0<=Y<1, X+Y+Z=1), He is a group III-V semiconductor written by aluminum<sub>X</sub>Ga<sub>Y</sub>In<sub>Z</sub>N<sub>1-Q</sub>M<sub>Q</sub> (0<=X<1, 0<=Y<1, X+Y+Z=1, and the sign M are the Vth group element other than nitrogen; and are 0<=Q<1).

[0003] In group III nitride semiconductor light emitting elements, such as LED or LD, gallium nitride indium (Ga<sub>X</sub>In<sub>1-X</sub> N: 0<=X<=1), Although it has a band gap suitable for emitting short wavelength visible light therefore, it is utilized as a luminous layer of a group III nitride semiconductor light emitting element (refer to JP,55-3834,B). The light-emitting part of these light emitting devices is the purpose of gaining the short wavelength visible light of high intensity, and it is common to comprise a pn junction type double hetero (DH) structure (for example, above-mentioned Jpn.J.Appl.Phys. and Vol.34 (1995) reference). A luminous layer is constituted from Ga<sub>X</sub>In<sub>1-X</sub>N (0<=X<=1) which consists of polyphase (multi-phase) structure which consists of two or more phases (phase) which are different in indium composition (=1-X), The art of obtaining a high-intensity group III nitride semiconductor light emitting element is also indicated (refer to American patent US-No. 5,886,367).

[0004] Being in conventional pn junction type DH structure, generally p form or n form barrier layer which pinches a luminous layer comprises group III nitride semiconductors, such as p form or gallium aluminum nitride (aluminum<sub>X</sub>Ga<sub>1-X</sub> N: 0<=X<=1) of n form. In order that GaN system material may present conduction of n form in the state of what is called undoped (undope) that does not add an impurity intentionally (refer to JP,53-20882,A specification), it is the common knowledge which the aluminum<sub>X</sub>Ga<sub>1-X</sub>N layer of n form tends to form. On the other hand, the aluminum<sub>X</sub>Ga<sub>1-X</sub>N layer of p form is chiefly formed with a means to dope magnesium (Mg) as p type impurities. However, Mg is electrically inactivated by the hydrogen which invades in a growth phase at the time of the membrane formation (refer to the patent No. 2872096 gazette). For this reason, it is also publicly known not to be obtained by stabilizing the p form aluminum<sub>X</sub>Ga<sub>1-X</sub>N layer of low resistance in the state of as-grown (refer to JP,61-7671,A specification).

[0005] In order to obtain the p form aluminum<sub>X</sub>Ga<sub>1-X</sub>N layer of the low resistance needed for constituting pn junction type DH structure, in the former. A means to heat-treat 400 \*\* at the above temperature after membrane formation is adopted to the as-grown growth phase by which the p type impurities which once formed membranes were doped (refer to patent No. 2540791). Or a means to irradiate with an electron beam under vacuum environment for the aluminum<sub>X</sub>Ga<sub>1-X</sub>N growth phase by which the p type

impurities of an as-grown state were added, and to activate p type impurities electrically is taken (refer to patent No. 2500319).

[0006] In the former, the composition which takes out luminescence from the surface side of a p form III fellows compound semiconductor growth phase outside is large number of people. That is, for example, it has been arranged in the upper part of a luminous layer, it has composition which takes out luminescence from the p form aluminum<sub>x</sub>Ga<sub>1-x</sub>As (0≤X≤1) barrier layer side outside. For this reason, if it is in GaN system LED of a conventional type, in order that the electrode provided above a top barrier layer may raise the extraction efficiency of luminescence to the exterior, it mainly comprises material of transparence or translucency. For example, the composition which provides the electrode which consists of layered structure of gold (Au) and nickel (nickel) on the transparent electrode which consists of indium oxide and tin (abbreviation: ITO), and its transparent electrode is indicated via the GaN system semiconductor layer which added p type impurities (refer to patent No. 2661009). It is known that the electrode which consists of composition which inserted nickel oxide (NiO) between Au and nickel is translucency (refer to patent No. 2916424). The contact (contact) layer which consists of p form GaN is made to intervene, and the art which arranges the zinc oxide (ZnO) layer by which aluminum (aluminum) was added as an ohmic contact layer of an Au electrode is indicated (refer to American patent US No. 5,889,295).

---

[Translation done.]

**\* NOTICES \***

JPO and INPIT are not responsible for any damages caused by the use of this translation.

- 1.This document has been translated by computer. So the translation may not reflect the original precisely.
- 2.\*\*\* shows the word which can not be translated.
- 3.In the drawings, any words are not translated.

---

**EFFECT OF THE INVENTION**

---

[Effect of the Invention] Since it had composition which provides the transparent oxide layer which presents p form conductivity which makes a p type barrier layer, p form electrode layer, and p form window layer serve a double purpose on a luminous layer when depending on this invention, The light-emitting part of pn junction type heterojunction structure can be constituted from a group III nitride semiconductor like the former, without requiring the complicated process at the time of forming the p type layer of low resistance, and if the light-emitting part which consists of this composition is used, a high-intensity group III nitride semiconductor light emitting element can provide simple.

[0042] When depending on this invention, since a transparence p type oxide layer is constituted on the basis of the band gap of the matrix phase which constitutes the luminous layer which consists of polyphase structures, forward voltage is low and the high-intensity group III nitride semiconductor light emitting element to which the emission area was expanded is provided.

---

[Translation done.]

## \* NOTICES \*

JPO and INPIT are not responsible for any damages caused by the use of this translation.

1. This document has been translated by computer. So the translation may not reflect the original precisely.
2. \*\*\*\* shows the word which can not be translated.
3. In the drawings, any words are not translated.

---

## TECHNICAL PROBLEM

---

[Problem(s) to be Solved by the Invention] Like the above, a means to constitute a pn junction type light-emitting part using the group III nitride semiconductor growth phase formed by the epitaxial grown method is complicated. Requiring the special processing for activating p type impurities electrically after the epitaxial growth for obtaining p form group III nitride semiconductor layer of low resistance especially is also increase of the complicated nature of a process, and a cause to which the productive efficiency of a group III nitride semiconductor light emitting element is reduced remarkably. The problem in this conventional technology is thought out with that by which solution is achieved by a means to, constitute an electron hole (hole) feed layer from material of the low resistance different from the III group nitride semiconductor crystal layer of p form which can have and form a simple means for example.

[0008] In the conventional composition which provides directly the transparent electrode which consists of transparent oxides on the group III nitride semiconductor layer by which p type impurities were doped, there is inconvenience by which good ohmic (Ohmic) contact nature is not revealed by being stabilized by the transparent oxide material and the group III nitride semiconductor layer which constitute an electrode. This originates also in the difference in the band gap of the III group nitride semiconductor crystal layer and transparent oxide electrode which constitute a light emitting device having become large extremely. For this reason, if it is in LED and is in forward voltage (what is called  $V_f$ ) and LD, the problem that threshold voltage (what is called  $V_{th}$ ) cannot be reduced effectively is produced.

[0009] The example of the measure which improves the ohmic contact nature of a transparent conductive oxide layer and an LED composition layer, It can grasp to the conventional technology about aluminium phosphide gallium indium ( $\text{Al}_{1-x}\text{Ga}_x\text{In}_{1-y}\text{P}_y$ ,  $0 \leq x \leq 1$ ,  $0 < y \leq 1$ ) LED. For example, after inserting gallium arsenide (GaAs),  $\text{In}_x\text{Ga}_{1-x}\text{P}$ , etc. as a contact layer which expects improvement in ohmic contact nature, the transparent oxide layer is made to stratify in the invention indicated to JP,11-17220,A. In the invention indicated to JP,11-4020,A, AlGaInP system LED which consists of composition which arranges uniformly a zinc (Zn) film or an Au-Zn alloy film all over p form compound semiconductor layers directly under a transparent oxide layer, such as ITO and ZnO, is indicated.

[0010] However, if the above-mentioned conventional technology concerning AlGaInP system LED which emits luminescence of a red lamp color or a yellow zone is simply diverted more to the blue of short wavelength, or the group III nitride semiconductor light emitting element of a green zone, the inconvenience to which the transmission efficiency of luminescence to the exterior is reduced will be produced. In the above-mentioned metal membrane, still more, a contact layer is constituted, for example, also by GaAs, since it is small compared with the band gap to which a band gap \*\*\*\*s in blue glow or green light, luminescence will be absorbed. Namely, a means to arrange a metal membrane in order to make good ohmic contact nature with a transparent oxide layer, A conventional means to arrange the electrode formation (contact) layer which consists of a semiconductor material made smaller than the band gap converted from the wavelength of luminescence which should be penetrated cannot fully be applied to a high-intensity group III nitride semiconductor light emitting element.

[0011] Sufficient performance to penetrate luminescence of the short wavelength emitted from a  $\text{Ga}_x\text{In}_{1-x}\text{N}$  ( $0 \leq x \leq 1$ ) luminous layer is had and combined, and, in the case of group III nitride semiconductor material, it is a different transparent material of p form of low resistance, If the light-emitting part of pn junction type heterojunction structure is constituted, a high-intensity group III nitride semiconductor light emitting element can be provided. If it is the material which manifests itself good ohmic contact nature with the group III nitride semiconductor composition layer which constitutes a group III nitride

semiconductor light emitting element, it will become still more convenient gaining a high-intensity group III nitride semiconductor light emitting element. The composition in which such a demand is satisfied has not come [ however, ] to be indicated in the actual condition. Especially about the luminous layer which consists of  $\text{Ga}_x\text{In}_{1-x}\text{N}$  ( $0 \leq x \leq 1$ ) of polyphase structure by which bringing about luminescence of high intensity is known, (Refer to British patent GB2316226B), The requirements for revealing the transparent conductive material of p form which is excellent in the permeability of luminescence, and the good ohmic contact characteristic are strange.

[0012]this invention having conquered the technical problem which the above-mentioned conventional technology holds, having been made for the purpose of being stabilized and providing a high-intensity group III nitride semiconductor light emitting element simple, and, Since the light-emitting part of a pn junction type hetero structure is especially constituted using the conduction layer of p form which can be formed easily, indispensable requirements are shown on the basis of the band gap of a luminous layer.

---

[Translation done.]

## \* NOTICES \*

JPO and INPIT are not responsible for any damages caused by the use of this translation.

1. This document has been translated by computer. So the translation may not reflect the original precisely.
2. \*\*\*\* shows the word which can not be translated.
3. In the drawings, any words are not translated.

---

## MEANS

[Means for Solving the Problem] An artificer reached this invention, as a result of carrying out efforts examination wholeheartedly that the above-mentioned technical problem should be solved. Namely, a barrier layer which this invention becomes from a group III nitride semiconductor of n form as [1] light-emitting part, A group III nitride semiconductor light emitting element containing a luminous layer which consists of an indium content group III nitride semiconductor, and a p type layer which consists of oxides, [2] A group III nitride semiconductor light emitting element given in [1], wherein a luminous layer comprises a group III nitride semiconductor (multilayer-structure luminous layer) of two or more phases which are different in indium concentration, [3] [1], wherein a band gap of a p type layer which consists of oxides is larger than a band gap corresponding to a luminous wavelength emitted from a luminous layer, or a group III nitride semiconductor light emitting element given in [2], [4] A p type layer which consists of oxides receives luminescence with a wavelength of 400 nm – 600 nm, A group III nitride semiconductor light emitting element given in any 1 paragraph of [1] – [3] having the transmissivity of not less than 40%, [5] A band gap of a p type layer which consists of a group III nitride semiconductor light emitting element given in any 1 paragraph of – [4] and [2] [6] oxide, wherein a band gap of a p type layer which consists of oxides is more than a band gap of a matrix phase which constitutes a multilayer-structure luminous layer, A group III nitride semiconductor light emitting element given in [5], wherein a difference with a band gap of a matrix phase which constitutes a multilayer-structure luminous layer is 1.0 eV or less, [7] A group III nitride semiconductor light emitting element given in any 1 paragraph of [1] – [6], wherein a p type layer which consists of oxides comprises an oxide containing copper, [8] A group III nitride semiconductor light emitting element given in [7], wherein a p type layer which consists of oxides is  $\text{CuAlO}_2$ , [9] A group III nitride semiconductor light emitting element given in [8], wherein thickness of a p type layer which consists of oxides is 5 nm – 500 nm, [10]  $\text{CuAlO}_2$  between a p type layer and a luminous layer which are set to [8] being the polycrystalline substance or [9] from a group III nitride semiconductor light emitting element of a statement, and [11] oxides, It is related with any 1 paragraph of [1] – [10], wherein it has a group III nitride semiconductor layer written by  $\text{aluminum}_x\text{Ga}_y\text{In}_z\text{N}$  ( $0 < X \leq 1$ ,  $0 \leq Y < 1$ ,  $X+Y+Z=1$ ), without a group III nitride semiconductor light emitting element of a statement.

[0014]

[Embodiment of the Invention] The feature in a 1st embodiment of this invention is not from p form group III nitride semiconductor material about the p type layer which constitutes the light-emitting part of pn junction type heterojunction structure, and there is in constituting from an oxide material which presents the conductivity of p form. as an oxide material -- copper oxide ( $\text{Cu}_2\text{O}$ ), and lanthanum trioxide strontium and copper ( $\text{La}_{2-x}\text{Sr}_x\text{CuO}_4$ ;  $X=1$  or  $2$ ) (Mat.Res.Soc.Symp.Proc. and Vol.156 (1989).) It can constitute from perovskite crystals, such as refer to the 183–188 page. Lanthanum trioxide calcium rhodium ( $\text{La}_{1-x}\text{Ca}_x\text{RhO}_3$ ), Superconductivity oxide materials ("physical-properties science selected-books .), such as lanthanum trioxide strontium rhodium ( $\text{La}_{1-x}\text{Sr}_x\text{RhO}_3$ ) and lanthanum trioxide barium rhodium ( $\text{La}_{1-x}\text{Ba}_x\text{RhO}_3$ ) It can constitute also from an electroconductive oxide (revised edition)" (Shokabo Publishing Co., Ltd., August 10, 1997 issue, the 6th edition of revision), and refer to the 29 page.

[0015] The band gap corresponding to the wavelength of luminescence emitted from the luminous layer which consists of an n form or  $\text{Ga}_x\text{In}_{1-x}\text{N}$  ( $0 \leq X \leq 1$ ) of p form is exceeded, And the transparence p type electrode layer which makes the barrier layer of p form serve a double purpose can be constituted from an oxide material of p form conductivity which has a band gap exceeding the band gap of a luminous layer,



and it is desirable. That is, if it depends on this invention, a p type barrier layer is constituted from group III nitride semiconductor material, the complicatedness of the conventional technology which needs a tail end process after membrane formation can be avoided, and the light-emitting part of the pn junction hetero structure where the transparent electrode layer which makes \*\*\*\* and a barrier (clad) function serve a double purpose was provided can be constituted. A pn junction hetero light-emitting part is a hetero structure which pinches n form or the single luminous layer of p form by the barrier layer of both p form and n form, or is single or a pn junction type hetero light-emitting part which pinches multiple quantum well structure. For example, there is composition of the pn junction type light-emitting part which consists of an n form GaN barrier layer / the quantum well structure luminous layer / p form oxide barrier layer which consists of a  $\text{Ga}_x\text{In}_{1-x}\text{N}$  ( $0 \leq x \leq 1$ ) well layer and n form aluminum  $\text{Ga}_{1-x}\text{N}$  ( $0 \leq x \leq 1$ ) barrier layer n forms. It is contained in a 1st embodiment even if it is any of a well layer or a barrier layer to be in the luminous layer of quantum well structure, and to make it join to n form and a p type barrier layer.

[0016] If a luminous layer is constituted from a group III nitride semiconductor of the polyphase structure which is different in indium concentration, luminescence of high intensity will be brought about, and if especially a group III nitride semiconductor is set to  $\text{Ga}_x\text{In}_{1-x}\text{N}$  ( $0 \leq x \leq 1$ ), a more suitable luminous layer can consist of a 2nd embodiment of this invention.

[0017] The matrix phase (matrix-phase) which specifically [ polyphase structure ] occupies most luminous layers in volume. Although volume occupied from a matrix phase is made small, it is an internal crystalline-structure structure which comprises a subordinate phase (sub-phase) which makes indium composition (concentration) larger than a matrix phase (refer to JP,10-56202,A specification). A subordinate phase usually exists as a micro crystallite object which are scattered in a matrix phase. In order to be for example, an approximate sphere form about shape and to make the diameter uniform, It can attain with regulation of the heating rate in the temperature up or temperature fall, and cooling cycle which the luminous layer concerned wears after the end of membrane formation of a  $\text{Ga}_x\text{In}_{1-x}\text{N}$  ( $0 \leq x \leq 1$ ) luminous layer, or a cooling rate (refer to above British patent GB2316226B). If it has composition which combined the oxide layer of p form conductivity with the luminous layer which has such internal crystalline-structure composition, there is an advantage which the light-emitting part of the pn junction type hetero structure of bringing about luminescence of high intensity can constitute simple.

[0018] In a 3rd embodiment of this invention, when constituted from material of the band gap exceeding the band gap which \*\*\*\*s p form oxide layer in the luminous wavelength from a luminous layer regardless of the internal crystalline structure of a luminous layer, p form oxide layer which serves also as the transmission layer (window (window) layer) of luminescence to the exterior can be constituted, and it is convenience. If it is preferably made higher [ about 0.1 – 0.3 electron volt (unit: eV) of abbreviation ] than the band gap (band-gap) of a luminous layer, also when penetrating luminescence, and also when p form oxide layer demonstrates a barrier operation, it becomes convenient. p form oxide which demonstrates the transmissivity of not less than 40% can be used especially suitably to obtain high-intensity LED especially about luminescence which makes it the wavelength emitted from an indium content group III nitride semiconductor luminous layer, and is in the range of 400 nm – 600 nm so that it may describe in a 4th embodiment. As transmissivity is high, it is more convenient for obtaining high-intensity LED. The extraction efficiency of luminescence to the exterior gets worse rapidly with transmissivity being less than 40%.

[0019] It is in  $\text{Ga}_x\text{In}_{1-x}\text{N}$  ( $0 \leq x \leq 1$ ), and a band gap will become small if an indium composition ratio becomes large (refer to above-mentioned JP,55-3834,B). Therefore, for example, it is in the luminous layer which consists of  $\text{Ga}_x\text{In}_{1-x}\text{N}$  ( $0 \leq x \leq 1$ ) of polyphase structure, The band gap of  $\text{Ga}_{x1}\text{In}_{1-x1}\text{N}$  ( $0 < x1 \leq 1$ ) which constitutes a subordinate phase is smallness from it of  $\text{Ga}_{x2}\text{In}_{1-x2}\text{N}$  ( $0 \leq x2 < x1 < 1$ ) which makes a matrix phase. The oxide material which makes a band gap larger than it on the basis of a subordinate phase was chosen, and it does not necessarily exceed the band gap of a matrix phase. Since "falling" with potential conducting zone or valence band will occur in the joining interface of a polyphase structure luminous layer and p form oxide layer if p form oxide layer of the band gap which is less than a matrix phase by making a band gap large rather than a subordinate phase is joined, The cladding (cladding) operation exerted on a career (carrier) becomes weak, and it becomes less enough "a career shut up" up in a luminous layer. Therefore, it becomes inconvenient obtaining luminescence of high intensity. Therefore, at a 5th embodiment, p form oxide layer at the time of using the luminous layer of the polyphase structure which consists of an ingredient which is different in a band gap consists of oxide

materials which make a band gap larger than it on the basis of the band gap of a matrix phase.

[0020]However, if the potential barrier of p form oxide layer and a luminous layer is superfluously expensive, although the effect "which luminescence shuts up" will be demonstrated, circulation of a carrier (carrier) is checked, and if spread, the inconvenience which raises  $V_f$  or  $V_{th}$  to \*\* arises.

Therefore, at a 6th embodiment, the difference of the band gap of p form oxide layer and the band gap of the matrix phase of a luminous layer shall consist of materials which carry out 1.0 eV the following.

[0021]If the oxide crystal which contains copper (Cu) as a composing element is generally compared with other oxide crystals, the oxide which gives low (small) resistance will be obtained so that it may describe in a 7th embodiment. Therefore, p form oxide crystal layer which uses copper as a composing element can be used with sufficient convenience by constituting the pn junction light-emitting part of the embodiment of this invention.  $Cu_2O$ , and the aluminum oxide and copper ( $CuAlO_2$ ) of the above [ oxide crystal ] which use copper as a composing element, There are delafossite (delafossite) crystal forms ( $CuMO_2$ :M is a trivalent metal ion), such as strontium oxide and copper ( $CuSrO_2$ ), gallium oxide, copper ( $CuGaO_2$ ).

[0022]Especially  $CuAlO_2$  by the general sputtering (sputtering) method or the laser abrasion (laser ablation) method. Resistivity is used and the low resistance p type crystal layer of 1 ohm-cm can form membranes simple (refer to "Nature", Vol.389, No.6654 (1997), 939 - 942 pages). Therefore, from  $CuAlO_2$ , the advantage from which p form oxide layer which is sufficient for constituting p form electrode layer at \*\*\*\*\* is obtained is about the complicated post process for low-resistance-izing separately after membrane formation.  $CuAlO_2$  is a transparent conductive crystal which sets a band gap to about 3.5 eV at a room temperature (above "Nature", Vol.389 reference). Therefore, sufficient luminescence transmission layer (window layer) to penetrate luminescence of a near-ultraviolet zone to the green zone emitted from a  $Ga_xIn_{1-x}N$  ( $0 \leq x \leq 1$ ) luminous layer can consist of  $CuAlO_2$ . The difference in a band gap with GaN which sets a band gap to about 3.4 eV is set to about 0.1 eV. Therefore, the oxide layer joinable with the moderate barrier height which is transparent and has the conductivity of p form comprises  $CuAlO_2$ , for example to the  $Ga_xIn_{1-x}N$  ( $0 \leq x \leq 1$ ) luminous layer of the polyphase structure made into a matrix phase in GaN. According to this, therefore an 8th embodiment, it makes it suitable to constitute p form oxide layer from  $CuAlO_2$ .

[0023]According to a 9th embodiment, the thickness of  $CuAlO_2$  is preferably set as not less than 5 nm. It is because it does not come to cover the whole surface of the surface of a luminous layer with less than 5 nm uniformly. It is in this invention used as an electron hole feed layer by making  $CuAlO_2$  of p form into a p type barrier layer, and an electron hole cannot fully be supplied to a luminous layer as thickness is smallness. On the other hand, if it is the thickness over 500 nm, unevenness of the surface of a p form  $CuAlO_2$  layer will become remarkable, and the extraction efficiency to the exterior of luminescence will fall notably for the scattered reflection in the surface of a same layer. Therefore, the thickness of a p form  $CuAlO_2$  layer is restricted to 500 nm at the maximum. When depending on sputtering process or a laser ablation method and forming a p form  $CuAlO_2$  layer, the thickness of a same layer can be controlled with adjusting membrane formation time.

[0024] $Cu$  which constitutes  $CuAlO_2$  is an easily diffusive element, and the case where it spreads and invades in the luminous layer which consists of group III nitride semiconductors is possible. Copper serves as a luminescence center (color center) with group III nitride semiconductors, such as GaN (J. refer to Appl.Phys., Vol.47, No.12 (1976), and 5387-5390 pages). Therefore, luminescence which is excellent in monochromaticity consists is hard to be obtained of a group III nitride semiconductor luminous layer which copper mixed. This invention constitutes a p form  $CuAlO_2$  crystal layer from a polycrystalline layer so that it may describe in a 9th embodiment. If it is considered as the polycrystalline substance, many grain boundaries can be made inherent in it. If many grain boundaries are made to exist, a lot of copper is caught by the grain boundary, and the diffusion to a luminous layer can be controlled so much. For example, in order to form the p form  $CuAlO_2$  crystal layer of polycrystal by the argon (Ar) SUPARRINGU method, generally making forming temperature into the range of about 500 \*\* from a room temperature is recommended. It can be checked with the analyzing method, an electron diffraction method, etc. whether there is any formed p form  $CuAlO_2$  crystal layer with polycrystal.

[0025] In order to deter more effectively diffusion into the group III nitride semiconductor luminous layer of the composing element of p form oxide layer, or a cross inclusion, and invasion, as shown in a 10th embodiment, it becomes effective in the middle of a luminous layer and p form oxide layer to arrange the group III nitride semiconductor layer containing aluminum. Since aluminum is easy-oxidizability, the group III nitride semiconductor layer containing aluminum captures the oxygen which is isolated from the upper oxide layer, and spreads and invades into a luminous layer, and becomes effective also in controlling that a luminous layer oxidizes. The group III nitride semiconductor which contains aluminum as a composing element has an effect which a band gap is generally size, therefore can be taken out from the matrix phase which constitutes an indium content group III nitride semiconductor luminous layer to the exterior without absorbing most luminescence from a luminous layer.

[0026] aluminum content group III nitride semiconductor layer provided on a luminous layer becomes useful also as a protective layer which protects a luminous layer from the damage at the time of making p form oxide layer laminate by sputtering process on it again. About, the thickness of aluminum content group III nitride semiconductor layer which becomes effective in reducing the concentration of Cu which invades into a luminous layer, or oxygen (O), and controlling damage to a luminous layer exceeds 1 nm, and the range of it is about 100 nm or less. Are in a group III nitride semiconductor light emitting element, and aluminum content group III nitride semiconductor layer, It is preferred that it is a low carrier concentration layer which sets thickness to 50 nm or less at not less than 2 nm so that it may depend on the tunnel (tunnel) effect efficiently and the electron hole (hole) supplied from p form oxide layer as an electron hole feed layer can be poured in to a luminous layer.

[0027] The Al composition ratio of aluminum content group III nitride semiconductor layer has the effect of giving change to the wavelength of luminescence emitted from a luminous layer. For example, when the crystal layer which consists of gallium aluminum nitride ( $\text{aluminum}_x\text{Ga}_{1-x}\text{N}$ ;  $0 \leq x \leq 1$ ) is made into the above-mentioned protective layer or a diffusion prevention layer, the wavelength of luminescence emitted from the luminous layer of the same specification turns into long wavelength from the increase in an aluminum composition ratio ( $=x$ ). For example, a luminous wavelength when the same  $\text{Ga}_{0.88}\text{In}_{0.12}\text{N}$  luminous layer of thickness is entitled the  $\text{aluminum}_{0.85}\text{Ga}_{0.15}\text{N}$  layer which sets thickness to about 20 nm, It is set to about 510 to about 530 nm when the  $\text{aluminum}_{0.20}\text{Ga}_{0.80}\text{N}$  layer which sets thickness to about 20 nm is made to laminate to being set to about 450 nm – about 460 nm. It is in the tendency for luminescence of long wavelength to be concluded, so that the thickness of a luminous layer is small, when an  $\text{aluminum}_x\text{Ga}_{1-x}\text{N}$  ( $0 \leq x \leq 1$ ) layer is incidentally entitled. This has suggested that a luminous wavelength is changed by the size of distortion which a luminous layer wears between an  $\text{aluminum}_x\text{Ga}_{1-x}\text{N}$  layer and a  $\text{Ga}_x\text{In}_{1-x}\text{N}$  luminous layer. However, when an aluminum composition ratio is too high, a band gap is good for becoming large and carrying out light transmission of the luminescence, but it may become a conduction resistor of element operating current. So, as for the aluminum composition ratio of an aluminum content group III nitride semiconductor, it is preferred to use that it is high with about 0.25 – about 0.30 range.

[0028] The light emitting device concerning this invention makes p form pedestal electrode laminate on p form oxide layer in the 1–10th above-mentioned embodiments, and is constituted. Since p form oxide layer of this invention is a conductive layer which can diffuse element operating current horizontally, like conventional technology, it does not need to dare to provide the metal tunic which worsens permeability like Au–nickel or Au–NiO–Au in the surface of p form group III nitride semiconductor layer, and does not need to achieve current diffusion. When p form electrode layer is constituted from an oxide layer of p form conductivity, the pedestal electrode which is excellent in ohmic contact nature may be formed. p form pedestal electrode can consist of suitably publicly known nickel, NiO, an Au–Zn alloy, an Au–beryllium (Be) alloy, an In–Zn alloy, etc. On the other hand, the ohmic electrode of n form can consist of nickel, NiO, In, antimony (Sb), antimony oxide, an Au–germanium alloy, an Au–tin (Sn) alloy, and an In–Sn alloy, for example. In the case where conductive crystals, such as silicon (Si), SiC, or gallium phosphide (GaP), are used as a substrate, it can provide in the rear-face side of a substrate, and is convenience.

## \* NOTICES \*

JPO and INPIT are not responsible for any damages caused by the use of this translation.

1. This document has been translated by computer. So the translation may not reflect the original precisely.
2. \*\*\*\* shows the word which can not be translated.
3. In the drawings, any words are not translated.

---

## EXAMPLE

[Example](Example 1) By this example, the case where the blue LED 10 is constituted from the laminated structure body 20 provided with transparent p form conductive oxide layer which serves both as a p type barrier layer, p form window layer, and p form electrode layer (contact layer) is made into an example, and this invention is explained in detail. Drawing 1 is a cross section of LED10 concerning this example.

[0030] The laminated structure body 20, Sb doped n type Si single crystal substrate 101 and sphalerite type cubic Linné-ized boron (BP) are made into a subject. The n form buffer layer 102 which consists cubic BP formed at the elevated temperature from the 1st becoming buffer layer 102a and buffer layer 102a of n form of polycrystal of the 2nd buffer layer 102b of n form that becomes as a subject, the lower barrier layer 103 which consists of Si-doped n type GaN, and the matrix phase S are set to n form GaN, An average indium composition ratio. The gallium nitride indium mix crystal set to 0.1. ( $\text{Ga}_{0.9}\text{In}_{0.1}\text{N}$ ) consisted of the transparency p type conductive layers 106 which consist of the n form luminous layer 104, the protective layer 105 which is undoped and consists of aluminum<sub>0.8</sub>Ga<sub>0.2</sub>N of n form, and  $\text{CuAlO}_2$  of the polyphase structure made into the subordinate phase T.

[0031] The 1st and 2nd buffer layers 102a and 102b made boron triethyl ( $\text{C}_2\text{H}_5$ )<sub>3</sub>B the source of boron (B), and formed membranes by the MOCVD method which makes phosphine ( $\text{PH}_3$ ) the source of Linné (P).

The 1st buffer layer 102a of polycrystal formed membranes at 420 \*\*, in the atmosphere containing phosphine, it carried out temperature up of the temperature of the substrate 101 to 1050 \*\*, and the 2nd buffer layer 102b of the single crystal formed it, after ending membrane formation of the 1st buffer layer 102a. Each class of the epitaxial composition layers 102–105, It was made to grow up by trimethylgallium ( $\text{CH}_3$ )<sub>3</sub>Ga / trimethylaluminum ( $\text{CH}_3$ )<sub>3</sub>aluminum / trimethylindium ( $\text{CH}_3$ )<sub>3</sub>In / the ammonia ( $\text{NH}_3$ ) system decompression MO–VPE method. As a source of doping of silicon, the disilane hydrogen mixed gas which contains a disilane ( $\text{Si}_2\text{H}_6$ ) by the concentration of about 10 volume ppm was used. The forming temperature of the luminous layer 104 of polyphase structure was 890 \*\*, and the forming temperature of other group III nitride semiconductor growth phases 103 and 105 was 1050 \*\*. To the forming temperature of the n form protective layer 105, temperature up was carried out at the speed of about 150 \*\*/m in the ammonia air current after the end of membrane formation of the luminous layer 104. After finishing membrane formation of the n form protective layer 105, the temperature was lowered at the speed of about 50 \*\*/m from 1050 \*\* to 950 \*\*, and also was lowered at the speed of about 15 \*\*/m to 800 \*\*. The temperature fall to the temperature near the room temperature from 800 \*\* was based on natural air cooling. By the above temperature up and adoption of the temperature falling speed, equalization of the indium composition of the subordinate phase T which constitutes the luminous layer 104 of polyphase structure, outline shape, and a size was attained.

[0032] The thickness (d) of the 1st buffer layer 102a could be about 20 nm. The thickness of the 2nd buffer layer 102b set to about 2 micrometers, and carrier concentration (n) was made into abbreviation  $2 \times 10^{18} \text{cm}^{-3}$ . The lower barrier layer 103 set to d= 0.5 micrometer, and was taken as  $n=3 \times 10^{18} \text{cm}^{-3}$ . The luminous layer 104 set to d= 0.1 micrometer, and was taken as carrier concentration (n)  $=1 \times 10^{17} \text{cm}^{-3}$ . After finishing membrane formation and cooling the n form epitaxial growth layers 102–105 which constitute the laminated structure body 20 to a room temperature, the laminated structure body 20 was taken out from the MOCVD growth oven. Next, the temperature of the substrate 101 was made to laminate the transparency p type oxide conductive layer 106 which consists of  $\text{CuAlO}_2$  on the n form protective layer 105 as about 300 \*\* with general magnetron sputtering method. The pressure at the time

of sputtering was about 0.1 torr (Torr), and the high frequency (RF) electric power which carries out a seal of approval was about 150 W (W). The thickness of the p form oxide conductive layer 106 could be about 0.15 micrometer. The resistivity of the same layer 106 became about 2 ohm-cm at the room temperature. The transmissivity about blue belt light with a wavelength of 450 nm of the  $\text{CuAlO}_2$  film (thickness = 0.15 micrometer) which formed membranes on the glass substrate separately on the same conditions was about 68%. The band gap of GaN (band gap = 3.4 eV) which makes the matrix phase S which constitutes the luminous layer 104 of polyphase structure, and  $\text{CuAlO}_2$  whose band gap is about 3.5 eV was set to about 0.1 eV.

[0033] On the p form conductive oxide layer 106, in view of the ability of the same layer 106 to also make p form electrode layer serve a double purpose, the lower layer part 107a was used as titanium (Ti), and the pedestal electrode 107 which consists of layered structure which sets the upper levels 107b to aluminum was formed. The pedestal electrode 107 was made into the round shape which shall be about 140 micrometers in diameter. The thickness of lower layer Ti film 107a could be about 150 nm. The thickness of upper Al film 107b could be about 1 micrometer. The n form ohmic electrode 108 which consists of an aluminum-Sb alloy was made to laminate all over the rear-face side of conductive Si substrate 101. The thickness of the n form ohmic electrode 108 could be about 1 micrometer.

[0034] It divided into the chip shape which sets one side to about 350 micrometers, and made with individual LED10. Between the p form electrode 107 and the n form ohmic electrode 108, when conduction of the current of 20 mA (mA) was carried out to the forward direction, it had almost uniform intensity from the approximately whole area of the field of the peripheral wall of the p form electrode 107, and blue glow was emitted. The luminous wavelength measured by the spectroscope was about 445 nm. The half breadth of an emission spectrum is about 28 nm, and luminescence which is excellent in monochromaticity was obtained. Forward voltage (@20mA) was averaged and became 3.2-volt (V). The luminescence intensity in the chip state reached about 22 microwatts (microwatt).

[0035] (Example 2) By this example, the case where the blue LED 30 is constituted from the laminated structure body 40 provided with transparent p form conductive oxide layer is made into an example, and this invention is explained in detail. Drawing 2 is a cross section of LED30 concerning this example.

[0036] The laminated structure body 30 sets to n form  $\text{Ga}_{0.95}\text{In}_{0.05}\text{N}$  the silicon on sapphire (0001) 101, the GaN low temperature buffer layer 102, the n form barrier layer 103 that consists of Si-dope n type GaN, and the matrix phase S, The gallium nitride indium mix crystal ( $\text{Ga}_{0.85}\text{In}_{0.15}\text{N}$ ) which sets an average indium composition ratio to 0.15 consisted of the n form luminous layer 104 of the polyphase structure made into the subordinate phase T, and the transparence p type conductive layer 106 which consists of  $\text{CuAlO}_2$ .

[0037] The buffer layer 102 of polycrystal formed membranes at 430 \*\*. III fellows nitriding \*\*\* semiconductor layers 103, 104 other than low temperature buffer layer 102 were grown up by trimethylgallium / trimethylaluminum / cyclopentadienyl indium ( $\text{C}_5\text{H}_5\text{In}$ ) / the ammonia system ordinary pressure MO-VPE method. The forming temperature of the luminous layer 104 of polyphase structure was 880 \*\*, and the forming temperature of other group III nitride semiconductor growth phases 103 and 105 was 1030 \*\*. After the end of membrane formation of the luminous layer 104 was lowered to 800 \*\* at the speed of about 15 \*\*/m in the ammonia air current. The temperature fall to the temperature near the room temperature from 800 \*\* was made to cool automatically. By this temperature fall operation, equalization of the indium composition of the subordinate phase T which constitutes the luminous layer 104 of polyphase structure, outline shape, and a size was attained. As a source of doping of silicon, the disilane hydrogen mixed gas which contains a disilane by the concentration of about 10 volume ppm was used.

[0038] The thickness (d) of the buffer layer 102 could be about 17 nm. The n form barrier layer 103 set to  $d = 0.5$  micrometer, and was taken as carrier concentration (n)  $= 3 \times 10^{18} \text{ cm}^{-3}$ . The luminous layer 104 set to  $d = 0.1$  micrometer, and was taken as carrier concentration (n)  $= 1 \times 10^{17} \text{ cm}^{-3}$ . After finishing membrane formation and cooling the n form epitaxial growth layers 103 and 104 which constitute the laminated structure body 20 to a room temperature, the laminated structure body 20 was taken out from the MOCVD growth oven. Next, the temperature of the substrate 101 was made to laminate the transparence p type oxide conductive layer 106 which consists of  $\text{CuAlO}_2$  on the luminous layer 104 as about 300 \*\* with a general laser ablation method. The pressure at the time of covering was set to about 0.1 Torr(s). The thickness of the p form oxide conductive layer 106 could be about 0.25 micrometer. The resistivity of the same layer 106 became about 1 ohm-cm at the room temperature. The transmissivity about blue belt

light with a wavelength of 450 nm of the  $\text{CuAlO}_2$  film (thickness = 0.25 micrometer) which formed membranes on the glass substrate separately on the same conditions was about 62%. The band gap of  $\text{Ga}_{0.95}\text{In}_{0.05}\text{N}$  (band gap = 3.3 eV) which makes the matrix phase S which constitutes the luminous layer 104 of polyphase structure, and  $\text{CuAlO}_2$  whose band gap is about 3.5 eV was set to about 0.2 eV.

[0039] On the p form conductive oxide layer 106, in view of the ability of the same layer 106 to also make p form electrode layer serve a double purpose, the lower layer part 107a was set to Ti, and the pedestal electrode 107 which consists of layered structure which sets the upper levels 107b to Au was formed. The pedestal electrode 107 set the long side to about 300 micrometers, and made it the rectangle which sets a shorter side to about 120 micrometers. The thickness of lower layer Ti film 107a could be about 150 nm. The thickness of upper Au membrane 107b could be about 0.8 micrometer. The n form ohmic electrode 108 removes the conductive oxide layer 106 which serves as the p type barrier layer in the formation scheduled region, and the luminous layer 104 of polyphase structure by the plasma etching technique using Ar / methane ( $\text{CH}_4$ ) / hydrogen ( $\text{H}_2$ ) mixed gas. It formed in the layer part of the n form barrier layer 103 made to expose. The n form ohmic electrode 108 was constituted from aluminum, and the thickness set it to about 0.8 micrometer. The plane shape of the n form ohmic electrode 108 set the long side to about 300 micrometers, and made it the rectangle which sets a shorter side to about 120 micrometers. n form and the p form electrodes 107 and 108 of each other [ the position which counters mutually ] were arranged to abbreviated parallel.

[0040] Next, it divided into the chip shape which sets one side to about 350 micrometers, and made with individual LED30. Between the p form electrode 107 and the n form ohmic electrode 108, when conduction of the 20-mA current was carried out to the forward direction, it had almost uniform intensity from the approximately whole area of the field of the peripheral wall of the p form electrode 107, and blue-green light was emitted. The luminous wavelength measured by the spectroscopy was about 478 nm. The half breadth of the emission spectrum was set to about 32 nm. Forward voltage (@20mA) was averaged and was set to 3.1V. The luminescence intensity in the chip state reached about 16 microwatts.

---

[Translation done.]

## \* NOTICES \*

JPO and INPIT are not responsible for any damages caused by the use of this translation.

- 1.This document has been translated by computer. So the translation may not reflect the original precisely.
- 2.\*\*\*\* shows the word which can not be translated.
- 3.In the drawings, any words are not translated.

---

## DESCRIPTION OF DRAWINGS

---

[Brief Description of the Drawings]

[Drawing 1]It is a cross section of LED given in Example 1.

[Drawing 2]It is a cross section of LED given in Example 2.

[Description of Notations]

10 LED

20 Laminated structure body

30 LED

40 Laminated structure body

101 Monocrystal substrate

102 Buffer layer

102a The 1st buffer layer

102b The 2nd buffer layer

103 Lower barrier layer

104 Luminous layer

105 Protective layer

106 Transparence p type conductive oxide film

107 p form pedestal electrode

107a Electrode lower layer part

107b The upper levels of an electrode

108 n form ohmic electrode

S The matrix phase of a polyphase structure luminous layer

T The subordinate phase of a polyphase structure luminous layer

---

[Translation done.]



**\* NOTICES \***

JPO and INPIT are not responsible for any damages caused by the use of this translation.

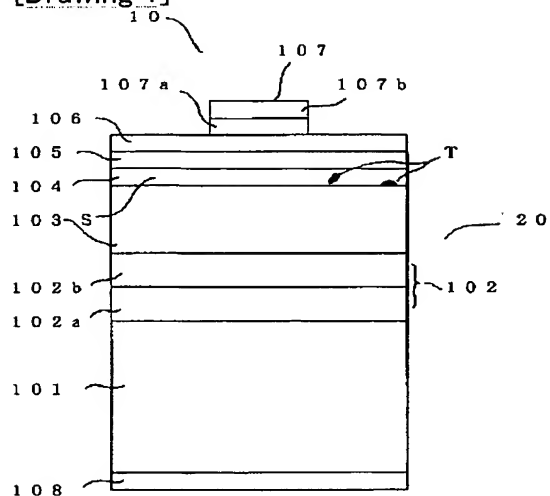
- 1.This document has been translated by computer. So the translation may not reflect the original precisely.
- 2.\*\*\*\* shows the word which can not be translated.
- 3.In the drawings, any words are not translated.

---

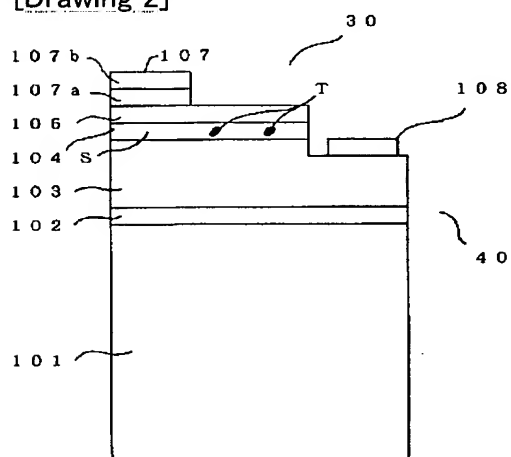
**DRAWINGS**

---

[Drawing 1]



[Drawing 2]



---

[Translation done.]

**\* NOTICES \***

JPO and INPIT are not responsible for any damages caused by the use of this translation.

1.This document has been translated by computer. So the translation may not reflect the original precisely.

2.\*\*\* shows the word which can not be translated.

3.In the drawings, any words are not translated.

---

**CORRECTION OR AMENDMENT**

---

[Kind of official gazette]Printing of amendment by regulation of 2 of Article 17 of Patent Law

[Section classification] The 2nd classification of the part VII gate

[Publication date]July 22 (2004.7.22), Heisei 16

[Publication No.]JP,2001-53338,A (P2001-53338A)

[Date of Publication]February 23, Heisei 13 (2001.2.23)

[Application number]Japanese Patent Application No. 11-227075

[The 7th edition of International Patent Classification]

H01L 33/00

H01L 21/205

H01S 5/32

[FI]

H01L 33/00 C

H01L 21/205

H01S 5/32

[Written amendment]

[Filing date]June 30, Heisei 15 (2003.6.30)

[Amendment 1]

[Document to be Amended]Specification

[Item(s) to be Amended]Claim

[Method of Amendment]Change

[The contents of amendment]

[Claim(s)]

[Claim 1]

A group III nitride semiconductor light emitting element comprising:

A barrier layer which consists of a group III nitride semiconductor of n form as a light-emitting part.

A luminous layer which consists of an indium content group III nitride semiconductor.

A p type layer which consists of oxides.

[Claim 2]

The group III nitride semiconductor light emitting element according to claim 1, wherein a luminous layer comprises a group III nitride semiconductor (multilayer-structure luminous layer) of two or more phases which are different in indium concentration.

[Claim 3]

The group III nitride semiconductor light emitting element according to claim 1 or 2, wherein a band gap of a p type layer which consists of oxides is larger than a band gap corresponding to a luminous wavelength emitted from a luminous layer.

[Claim 4]

A group III nitride semiconductor light emitting element given in any 1 paragraph of claims 1-3, wherein a p type layer which consists of oxides has the transmissivity of not less than 40% to luminescence with a

wavelength of 400 nm – 600 nm.

[Claim 5]

The group III nitride semiconductor light emitting element according to claim 2, wherein a band gap of a p type layer which consists of oxides is more than a band gap of a matrix phase which constitutes a multilayer-structure luminous layer.

[Claim 6]

The group III nitride semiconductor light emitting element according to claim 5, wherein a difference between a band gap of a p type layer which consists of oxides, and a band gap of a matrix phase which constitutes a multilayer-structure luminous layer is 1.0 eV or less.

[Claim 7]

A group III nitride semiconductor light emitting element given in any 1 paragraph of claims 1–6, wherein a p type layer which consists of oxides comprises an oxide containing copper.

[Claim 8]

The group III nitride semiconductor light emitting element according to claim 7, wherein a p type layer which consists of oxides is  $\text{CuAlO}_2$ .

[Claim 9]

The group III nitride semiconductor light emitting element according to claim 8, wherein thickness of a p type layer which consists of oxides is 5 nm – 500 nm.

[Claim 10]

The group III nitride semiconductor light emitting element according to claim 8 or 9, wherein  $\text{CuAlO}_2$  is the polycrystalline substance.

[Claim 11]

A group III nitride semiconductor light emitting element given in any 1 paragraph of claims 1–10, wherein it has a group III nitride semiconductor layer written by  $\text{aluminum}_X\text{Ga}_Y\text{In}_Z\text{N}$  ( $0 < X \leq 1$ ,  $0 \leq Y < 1$ ,  $X+Y+Z=1$ ) between a p type layer and a luminous layer which consist of oxides.

[Claim 12]

A barrier layer which consists of a group III nitride semiconductor of n form as a light-emitting part.

A luminous layer which consists of an indium content group III nitride semiconductor.

An oxide.

A p type layer which is a manufacturing method of a group III nitride semiconductor light emitting element provided with the above, and consists of oxides is formed with sputtering process or a laser ablation method.

[Claim 13]

A manufacturing method of the group III nitride semiconductor light emitting element according to claim 12, wherein a p type layer which consists of oxides comprises an oxide containing copper.

[Claim 14]

A manufacturing method of the group III nitride semiconductor light emitting element according to claim 13, wherein a p type layer which consists of oxides is  $\text{CuAlO}_2$ .

[Claim 15]

LED which becomes any 1 paragraph of claims 1–11 from a group III nitride semiconductor light emitting element of a statement.

---

[Translation done.]